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ABSTRACT

The significant accomplishments and events in computing at Dartmouth College during the period July 1, 1973 through June 30, 1976 are described in detail. The report is divided into six sections: (1) review of activities, (2) acquisition of equipment, (3) software development, (4) computer applications, (5) highlights of the first decade of the Kiewit Center, and (6) the 1973-76 use of the Dartmouth Time Sharing System. (CMV)

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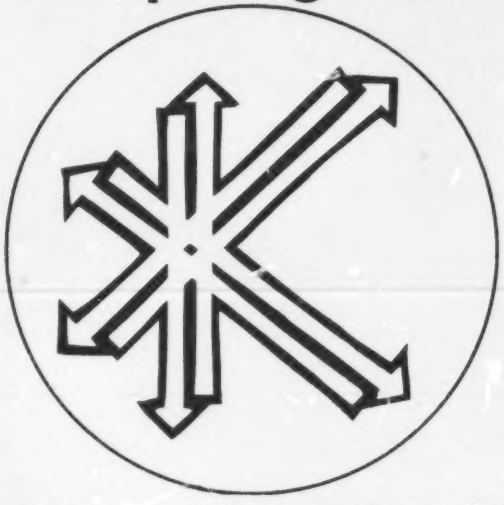
Computing at Dartmouth 1973-1976



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TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) AND USERS OF THE ERIC SYSTEM."

A report on the activities of the Kiewit Computation Center

EDITED BY THOMAS E. BYRNE & CHRISTINE W. THOMPSON

1 R006163

Acknowledgments

We are grateful to the entire Kiewit staff for their many contributions to the preparation of this report. Our special appreciation goes to Thomas E. Byrne and Christine W. Thompson, who wrote and edited much of the material included here, and to Marie Stebbins, who was primarily responsible for "on-line" editing of the manuscripts. Our thanks also to Ed Perkins for his graphics and to John Scotford for the cover design.

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"Those of us who have been associated with the Kiewit Computation Center over the years would like to take advantage of this occasion to express our deep appreciation to the man who led the center during its formative years and whose missionary vision contributed to the spread of the Dartmouth Time-Sharing System and the Kiewit philosophy of computing far beyond Hanover. . . , Tom Kurtz. . . ."

John S. McGeachie (right) awards a plaque to Thomas E. Kurtz (left) to commemorate his ten years of service to the Kiewit Computation Center and the Dartmouth Time-Sharing System.

This is the fifth in a series of reports on the activities of the Kiewit Computation Center prepared for the Trustees of Dartmouth College. It describes in detail the significant accomplishments and events in computing at Dartmouth College during the period July 1, 1973 through June 30, 1976. It also summarizes highlights of the first ten years of the Kiewit Center, which celebrated its tenth anniversary on December 2, 1976.

The report is dedicated to Thomas E. Kurtz, Director of the Kiewit Computation Center during most of its first decade of operation, and to a great extent chronicles the results of his leadership and vision.

J S McGeachie

John S. McGeachie
Director of Computing Services
Kiewit Computation Center

Contents

1 REVIEW OF ACTIVITIES

Instructional Use of Computing at Dartmouth 2
Off-campus Use of DTSS 3
Telenet Network 4
NERComP Network 4

2 ACQUISITION OF EQUIPMENT

The New Computer 6
Communications Facilities 6
H-716 Communications Processors 6
Terminals 7

3 SOFTWARE DEVELOPMENT

System Features 8
File Migration and Recovery 8
PERFORM Files 8
FIND 8
Slave-trap Programs 8
On-line Mail System 9
Priority Demonstration Queue Service 10
Shared Files 10
Telenet Communications Network 10
Operational Improvements 10

4 APPLICATIONS

Educational and Research Applications 11
Processing Satellite Data 11
Simulating Probability Theory 11
Visual Information Processing by the Human Brain 12
Identifying the X-ray Object Cygnus X-1 12
Fission-Track Dating 12
Project IMPRESS 13
BARON: Basic Archive for Research on Organizational Networks 13
Teaching Logic with a Program 13
Administrative Applications 14
Development Office 14
Office of the Registrar 14
Tuck School 15
Project FIND 16
Computerized Typesetting 16
Health Care Applications 16
Tumor Registries 16
Cancer Treatment 17

5 THE FIRST DECADE

Instructional Computing at Dartmouth 18
The Secondary School Project 18
The Pilot Regional Network 18
Project CONDUIT 19
The CCUC Conferences 19
Project COEXIST 20
Project COMPUTe 20
Pioneers Day 20
Tenth Anniversary 20
Symposium 20
Rededication Ceremony 21

6 USE OF DTSS: 1973-1976

Growth in the Use of DTSS 24
Use of Services 24
Availability of Services 25
Reliability 25
1972-73 through 1975-76 25
Monitoring System Failures 28
Use of DTSS Services 29
Profile of the User Session 29
February 1973, 1974 and 1975 29
February 1976 (and the H66/40) 31
The On-campus Users, 1973-76 32
Terminal Services 32
Central Processor Services 32
Saved Storage and I/O 36
Background Use of DTSS 36
I/O in Background 38
GCOS Use 38
Conclusions of the "Crunch Committee" 40

APPENDICES

A Highlights of the Kiewit Comments 41
B Kiewit Computation Center Staff 44
C Computing Contest Winners 47
D Usage Statistics 48

Tables & Illustrations

TABLES

1. Use of DTSS by Dartmouth Students, Fiscal 1975-76 3
2. Terminal Connect Hours Accumulated by Off-campus Users 4
3. Kiewit Student System Programming Assistants, 1973-74 through 1975-76 9
4. Utilization of G-635 Computer Hardware, 1972-1976 24
5. Availability of DTSS: February 1973, 1974, 1975, and April 1976 25
6. Reliability Summary, 1972-1977 26
7. Reliability of Dartmouth Time-Sharing System, 1972-1977 27
8. Average Terminal Hours Used Per Day, July 1972 through June 1976 30
9. Use of DTSS Foreground Services: February 1973, 1974, 1975, and 1976 30
10. Number of DTSS Users By Type, 1973-1976 31
11. Availability and Use of Services at Dartmouth 35
12. Use of Background Services, March through June 1973, 1974, 1975, 1976 38
13. Use of GCOS Services, Fiscal 1973-74 through 1975-76 39
14. Terminal Use By Time of Day and By Category of User 52
15. Central Processor Resources Consumed By Time of Day and By Category of User 52
16. Summary of DTSS System Performance During Annual Peak Usage, May 1973-1976 56
17. 66/40 Response Times, May 1976 57

FIGURES

1. Use of DTSS Services by Undergraduates 2
2. Dartmouth Educational Network and NERComP, 1976 5
3. Use of DTSS Services by Network Users, 1969-1976 5
4. DTSS Duplex Honeywell 66/40 System Configuration 7
5. Utilization of DTSS Computer Hardware During an Average 24-hour Period 26
6. Mean Time Between Failures (All Causes), 1971-1976 28
7. Number of Hardware Failures Per Month, 1971-1976 28
8. Number of Software Failures Per Month, 1971-1976 28
9. Growth in the Use of DTSS Services: Foreground and Background Processing, 1970-71 through 1975-76 33
10. Growth in the Use of DTSS Services: CPU Minutes Used Per Day, July 1970 through April 1977 34
11. Growth in the Use of DTSS Services: Input/Output Operations, 1971-72 through 1975-76 37
12. Relative Demand for Computer Resources By Different User Categories 48
13. Distribution of Users, Fiscal 1975-76, By Frequency of Use vs. Intensity of Use 49
14. Average Number of Simultaneous Users By Time of Day and By Day of Week 50
15. Percentage of Central Processor Used By Time of Day and By Day of Week 51
16. Terminal Use By Time of Day and By Category of User 53
17. Use of Input/Output Operations in Foreground 53
18. Use of Central Processor in Foreground By Category of User, May 27, 1976 53
19. Use of System Resource Units By Category of User, May 27, 1976 53
20. Comparison of System Resource Units Consumed by Dartmouth Undergraduates and Outside Users 54
21. Comparison of System Resource Units Consumed by Administrative and Kiewit Users 55
22. Terminal Connect Hours Per Day, 1973-1976 58
23. Daily Input/Output Use, 1973-1976 58
24. Number of Words Stored, 1973-1976 58

1. REVIEW OF ACTIVITIES 1973-1976

Between 1973 and 1976 two significant events occurred which will have lasting impact upon computing at Dartmouth: a new computer was installed, and the College's computing activities were restructured. These events marked the end of an era of spectacular growth and heralded the beginning of a period of growing maturity and stability in computing at Dartmouth.

By January 1974 the G-635 computer (then in its seventh year of operation) was saturated and was unable to accommodate further growth in the consumption of time-sharing services. Since the G-635 system could not be upgraded to meet the demands and since hardware failures were occurring more frequently, in late January 1976, the system was replaced with new and more powerful Honeywell 66/40 hardware. The acquisition of this new equipment — certainly the highlight of the three-year period — was to provide the nucleus of a hardware system designed to meet the College's computing needs for the next decade.

Of particular importance to computing at Dartmouth was the restructuring of computing activities. In September 1975 John S. McGeachie was named Director of Computing Services at Dartmouth and given responsibility for the administration and operation of both the administrative and academic computing facilities. Thomas E. Kurtz, Director of the Kiewit Computation Center for nearly a decade, was appointed Director of Academic Computing and made responsible for research in computing and for furtherance of the College's relationship with EDUCOM and other national and regional networking organizations.

The saturation of computer resources in the fall of 1973 was a major stimulus to research activities concerning computer hardware and usage trends. First, a feasibility study was carried out to justify the acquisition of the new computer, to evaluate potential replacement equipment, and to prepare for its eventual installation. Second, at the request of President John G. Kemeny, the Council on Computing studied the utilization of DTSS, analyzing usage patterns, growth trends, and the nature of system response under peak-load conditions. The results of the study by the so-called "Crunch Committee" were to serve as the basis for developing procedures to control the growth in demand for computer resources and to allocate computing resources equitably among users.

During this three-year period Dartmouth continued its role as a regional time-sharing resource through its own educational network, and through NERComP, the New England Regional Computing Program. In early 1976 Dartmouth began to offer its interactive programs, such as IMPRESS (a statistical data analysis and retrieval system), to colleges and universities from coast to coast over the Telenet data communication network.

Section 5 of this report reviews some of the highlights of the first decade of the Kiewit Computation Center, a decade which climaxed with an anniversary symposium entitled "Man and the Computer." This conference attracted national attention for its discussions of important public policy issues raised by computing. It is hoped that this experience will stimulate Dartmouth College to assume a leading role in promoting thoughtful, scholarly consideration of the social consequences of the computer's increasing impact on our everyday lives.

Much of the information included in section 6 is based upon the research done by the "Crunch Committee," its Chairman, Professor Victor McGee; and two committee members, Professors Irving Thomae and Dennis Thron. Credit for many of the statistical analyses incorporated in their final report belongs to John J. Korab, Jr., Tuck '77, who assisted the committee in carrying out the study. A summary of the conclusions of the Committee can be found at the end of section 6.

Instructional Use of Computing at Dartmouth

After a decade of use, instructional computing at Dartmouth has matured to the point where the novelty has worn off and its availability is taken for granted; however, instructors agree that to do without it would be "unthinkable." As shown by a 1975 survey of the instructional use of computing at Dartmouth, computing is an integral part of the academic environment. During the 1974-75 school year, one quarter of the faculty and three quarters of the undergraduates took part in courses which used computing; of the instructors who used computing, almost half responded that computing had played a significant role in their course.

The purpose of the survey, which was conducted by John M. Nevison and sponsored by Computing Services, was to measure the extent of instructional computing in undergraduate courses: the total amount, the range throughout the curriculum, and the variety of individual efforts. Its result was a snapshot of one year's course use. The survey's coverage was extensive; every person who taught an on-campus course from the 1974 summer term through the 1975 spring term was surveyed, and nearly eighty-three percent of the instructors responded, representing eighty-nine percent of the courses and ninety-two percent of the enrollment.

Computing has become "a matter of course" at Dartmouth, and the truth of this statement is supported by the survey's major findings, as summarized below:

- Over one quarter (29%) of the responding faculty used computing in a course during the school year studied.
- 43% of the responding faculty had used computing at some time in their research.
- 45% of the responding faculty had written a computer program. So, by definition, the *computing literacy rate* at Dartmouth was 45% among the faculty.
- The computing literacy rate among the Class of 1975 was over 70%.
- Computing was used in 12% of the sections of undergraduate courses offered at Dartmouth during the school year studied.

FIGURE 1

USE OF DTSS SERVICES BY UNDERGRADUATES
(STUDENTS ARE CLASSIFIED BY MAJOR)

- The usage by discipline was distributed as follows: 50% science, 35% social science, and 15% humanities.
- Computing takes a small amount of the average student's course time, but can vary a lot from student to student.
- This use was important; more often "integral" to the course than "supplemental" or "incidental."
- The "most important benefit" of computing was to develop intuition and sharpen insight into the subject, that is, to improve the course *qualitatively*.

The survey and its findings are documented in a 45-page report published by Computing Services, *Computing as a Matter of Course: The Instructional Use of Computers at Dartmouth College*. Copies of this report are available from the Documents Office, Kiewit Computation Center, Dartmouth College, Hanover, New Hampshire 03755.

TABLE 1

USE OF DTSS BY DARTMOUTH STUDENTS, FISCAL 1975-76

	PERCENT OF TOTAL UNDERGRADUATE USE	NUMBER OF USERS	CLASS TOTAL	PERCENT OF TOTAL
Undergraduates[a]				
Freshmen (1979)	44.1	904	1,056	85.6
Sophomores (1978)	21.6	716	999	71.7
Juniors (1977)	19.4	695	975	71.3
Seniors (1976)	14.9	517	864	59.8
Subtotal	100.0	2,832	3,894	72.7
Graduates[b]		565	632	89.1
Total		3,397	4,526	75.1

[a]Students in residence for at least one term during the period July 1975 - June 1976

[b]Based upon Fall Term enrollment in 1975

Off-campus Use of DTSS

Off-campus use reached its peak in 1973-74 and leveled off during the 1974-76 period, largely due to the saturation of the computer. Among remote users the most significant decline occurred among high school and "commercial" users; significant complementary growth was realized among college users, many of whom gain access to Dartmouth through NERComP. During 1975-76 NERComP users and the cadets at the Merchant Marine Academy were the largest off-campus users of DTSS.

During the fiscal year 1975-76, over 94,000 terminal hours and more than 600 hours of central processor services were used by off-campus organizations. For the year, this use accounted for 26.2% of all terminal hours and 14.6% of all system resources consumed.

By categories, however, there were some significant changes in the pattern of use, as shown in Table 2.

During 1975-76, there were active users from the following institutions:

Educational Institutions

Albion College
Barnes School
Bates College
Beaver College
Bernice A. Ray School
Lebanon College
Delta College
Veterans' Administration Hospital
Franklin Pierce College
Hanover Junior-Senior High School
Howard University
Hudson Valley Community College
International Law School
Jersey City Board of Education
Merchant Marine Academy
Mount Holyoke College
NERComP
New Hampshire College
New York Medical College
Skidmore College

Research and Other Nonprofit Institutions

Elliot Hospital
Energy & Power Subcommittee (U.S. Congress)
Hanover Conservation Council
Mt. Sinai School of Medicine
Narcotic Addiction Rehabilitation Center
National Opinion Research Center
Naval Aerospace and Regional Medical Center
New York Department of Education
Oak Ridge National Laboratory
Regional Center for Educational Training
Russell Sage Foundation
Sloan-Kettering Institute
Veterans' Administration Center
Vocational Rehabilitation Center

TABLE 2

TERMINAL CONNECT HOURS ACCUMULATED BY OFF-CAMPUS USERS

	1972-73	1973-74	1974-75	1975-76
High Schools	18,509	19,447	11,212	15,208
Colleges	59,776	69,352	74,414	70,978
Government	3,483	6,824	4,387	4,186
Commercial	8,418	10,985	3,899	3,746
Total	90,186	105,608	93,912	94,118

Telenet Network

In September 1973 Dartmouth College connected to the Telenet network via a direct, leased telephone line to Boston, Massachusetts. The Telenet connection made Dartmouth's time-sharing services accessible to people in major cities throughout the United States. The Telenet Communications network enables users to transmit data at speeds ranging from 50 bits per second up to 50 kilobits per second and accommodates many different transmission protocols.

In July 1976, Telenet users logged 555 terminal hours on the DTSS. By December, a monthly total of 710 terminal hours was logged as a result of about 1700 Telenet "sessions." We estimate that between 250 and 300 off-campus terminals gained access to DTSS via Telenet during 1975-76.

As we look to the future, we can expect that occasional use of unique Dartmouth software applications via Telenet will increase.

NERComP Network

NERComP (New England Regional Computer Program) is a not-for-profit organization which encourages and facilitates the exchange of computing resources among educational and nonprofit institutions in New England. NERComP provides physical communications facilities for the distribution of computing services offered by Babson College, Bowdoin College, Brown University, The Massachusetts Institute of Technology and Dartmouth College. Nearly 85% of all services distributed through NERComP are DTSS time-sharing services. The concepts of NERComP's organization and function have evolved over the past three years, and the development of the complex technical network once envisioned has been abandoned in the interest of bringing fiscal stability to the organization.

Use by NERComP-affiliated colleges is becoming a significant portion of total college use of the Dartmouth Time-Sharing System as shown by Table 10 (see section 6). In fiscal 1973, NERComP members accounted for 7,627 terminal connect hours; in 1976 they had accumulated nearly 15,000 hours.

New England colleges and universities which used DTSS via NERComP's network facilities during 1975-76 were:

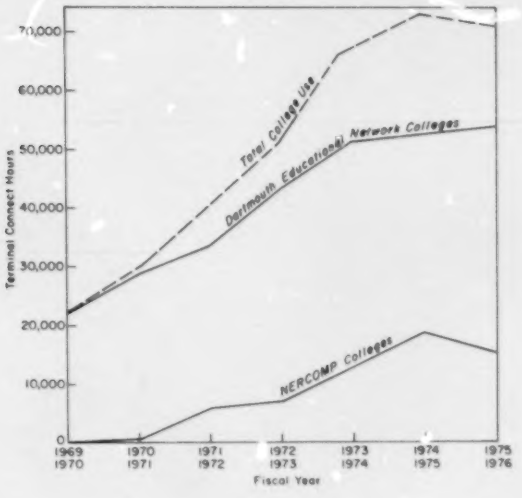
Babson College
Bates College
Bowdoin College
Emmanuel College
Harvard University
Merrimack College
M.I.T.
Simmons College
Trinity College
University of Hartford
Wellesley College
Western New England College
Worcester Polytechnic Institute
Yale University

FIGURE 2

DARTMOUTH EDUCATIONAL NETWORK
AND NERCOMP, 1976

FIGURE 3

USE OF DTSS SERVICES BY NETWORK USERS, 1969-1976



2. ACQUISITION OF NEW EQUIPMENT

A number of enhancements were made to Dartmouth's aging G-635 computer system in 1973 and 1974. Nevertheless, the reliability of the hardware deteriorated dramatically: the mean time between failures (MTBF) decreased from 75-100 hours in 1973 to 10-20 hours in 1974-75. Meanwhile, the rapid growth in demand for computing services at Dartmouth continued unabated; as a result, by mid-1973 Dartmouth's system was saturated and frequently overloaded. By 1975 College officials realized that the G-635 hardware configuration could no longer be practicably expanded: the cost of acquiring and maintaining upgraded components was too high relative to the expected improvements in service. At that point any improvements would have been stop-gap measures; at best, service would have improved only marginally.

Faced with this predicament, the College began to evaluate alternate computer configurations. In 1975, negotiations were initiated with Honeywell Information Systems, Inc., to acquire a Series 60 Level 66 system. Although Honeywell equipment was not the least expensive available, considerations of program conversion and continuity of service made it the most practical alternative at the time.

In January 1976, a dual processor Honeywell 66/40 system was installed at the Kiewit Computation Center. Of critical importance to Dartmouth's ability to purchase this system was a $500,000 gift from Peter and Evelyn Kiewit '22.

Dartmouth College formally agreed to purchase a Honeywell 66/40 computer in November 1975. Present at the contract signing ceremony were, from left to right: John S. McGeachie, Director of Computing Services, Dartmouth College; E. W. Corey, Branch Marketing Manager, Honeywell Information Systems, Inc.; John E. Dimitruk, Senior Account Manager, Honeywell Information Systems, Inc.; Rodney A. Morgan, Vice President for Administration, Dartmouth College; and Cary P. Clark, Assistant Legal Affairs Officer, Dartmouth College.

The New Computer

This system resulted in the following improvements in the computing services offered at Dartmouth:

- System reliability improved dramatically, from 10-20 hours MTBF in 1974 to 110 hours during the last six months of 1976 (see Table 7, section 6). Furthermore, the presence of duplicate components meant that when a failure did occur, the system was usually able to continue in operation, although at a reduced level.
- Response time, as perceived by users at terminals, improved.
- Computing capacity increased by about 30%, as predicted, and system use increased by 30% during 1975-76.
- File storage capacity increased by about 30% over previous levels.
- Perhaps most important, the system can be incrementally upgraded. Faster processors, memories and storage devices can be added as needed.

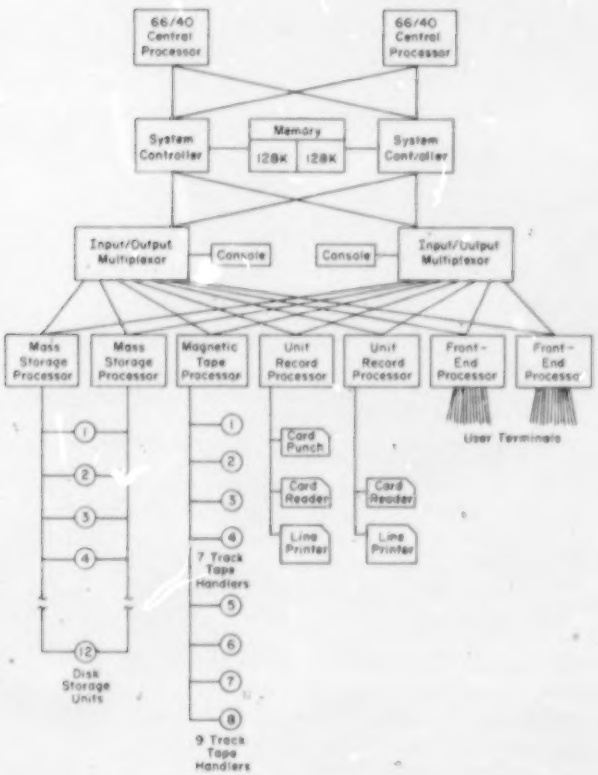
Communications Facilities

H-716 Communications Processors

In late 1973, the two ten-year-old Datanet 30 communications processors were replaced by two Honeywell 716 Terminal Communications Controllers. The H-716 systems provide much greater power and throughput, and can service over 250 users at speeds of 110 to 4800 bits per second. With the installation of the H-716 computers, the number of permissible simultaneous connections to the computer ("ports") increased

FIGURE 4

DTSS DUPLEX HONEYWELL 66/40 COMPUTER
SYSTEM CONFIGURATION AS OF DECEMBER 1, 1976



from 173 in the fall of 1973 to 239 in the winter of 1975. One 716 computer presently services 230 ports which transmit data at 110 to 2400 bits per second, while the other 716 serves a number of off-campus institutions as well as providing backup in case the primary machine fails.

Terminals

During 1975–76 the obsolescence of the Model 33 Teletypewriter became increasingly evident. In February 1976 Kiewit selected the following terminals as standard devices for the Dartmouth campus:

- LA-36 DECwriter II: an upper-lowercase terminal for standard interactive use; operates at 30 characters per second.
- Bedford System 75 Model II: an upper-lowercase terminal for typewriter-quality output suitable for the final preparation of manuscripts, letters, and camera-ready copy for offset printing; operates at 30 characters per second.
- Datamedia Elite 1520 CRT: an upper-lowercase, television-tube terminal for alpha-numeric display; operates at 30 or 120 characters per second, with the option of operating at 10 to 960 characters per second.
- Tektronix 4010 (or 4006) Graphics Terminal: an uppercase CRT terminal with high-resolution graphic input and output capabilities; can be connected to a hard-copy device; operates at 30 or 120 characters per second, with the option of operating at 10 to 960 characters per second.

In February 1976 the terminals shown in this photograph were chosen as standard for use on the Dartmouth campus. Back row, from left to right: Bedford System 75 Model II, Tektronix Graphics Terminal, LA-36 DECwriter II; front row, from left to right: keyboard and display screen of a Datamedia Elite 1520 CRT, and a portable terminal. (No final recommendation has been made concerning the selection of a specific portable terminal.)

3. SOFTWARE DEVELOPMENT

Since 1974 the efforts of the software development group have focused on new system features and operational improvements. A number of projects have been accomplished in these areas.

System Features

File Migration and Recovery

In July 1975 a file migration system was implemented. File migration is designed to increase the amount of mass memory (disk storage) available on the system. Its effect is to remove unused files from immediate-access disk storage and to store them on magnetic tape, a slower but more cost-effective medium. *All* files on the system (including system modules, library programs, etc.) "migrate" to magnetic tape if they have not been used for fourteen weeks. The periodic migration of unused files increases useable storage available on the disks and helps keep the file system in equilibrium.

Files which have migrated can be recovered by a simple command from a user's terminal and returned to disk storage. Recoveries are performed once a day, in the early morning, and users' files are generally recovered within 24 hours.

The migration/recovery system was further enhanced with the addition of user-initiated migration. Rather than wait for fourteen weeks of disuse to elapse, a user may request that a file migrate during the next weekly migration (usually on Sunday). This feature allows users to remove low-priority or little used files from their personal catalog of files and enables them to make better use of the storage allotted to them.

PERFORM Files

PERFORM files were instituted as a time-saving feature for users; they simulate the typing that would be done at a terminal to complete a task or a series of tasks. PERFORM files can contain line-numbered lines, system commands, and special commands to the PERFORM system.

When a PERFORM command is issued for a particular file, the system begins executing the commands in the PERFORM file. System commands in the file are printed on the terminal as they are executed, along with any terminal output generated (such as "READY," resources consumed, etc.). When the last command in the PERFORM file has completed, the system prints an additional "READY" message and the total resources consumed during the execution of the PERFORM file.

FIND

FIND is a management information system originally developed at Dartmouth in 1972. From 1972 until 1974 early versions of the system were widely used and well accepted by the DTSS user community. These early versions laid the groundwork for a faster and more versatile version of FIND on which development was begun in 1974. Development continued for two years, adding the capability to join different data bases, greatly expanding the power of the DEFINE command, improving and expanding the command syntax, and speeding up the operation of most commands.

The new version of FIND was officially released in August 1976. The RETRIEVE command was 2-3 times faster, SELECT was 2-20 times faster, input and output files were easier to create, and the new capabilities of the DEFINE command opened up a whole range of new FIND applications. Stimulated by the success of this version, the FIND staff will soon begin the planning process for an even more advanced version of FIND which should be available by 1979.

Slave-trap Programs

The ability to write slave-trap programs is an enhancement which provides better file security to experienced users. Slave-trap programs are a sophisticated means of protecting saved files;

TABLE 3

KIEWIT STUDENT SYSTEM PROGRAMMING ASSISTANTS

1973-74 THROUGH 1975-76

STUDENTS	AREA OF RESPONSIBILITY
James L. Cruce '72	Catalog, Algol
Louis F. Fernandez '73	Simon
Cloyd Lee Harris '73	Gcos Simulator
Allan W. Jayne '73	Typedit
Victor Kiarsis '73	Tape modules, Multrun
Carl L. Pedersen '73	Edit, Text, String
A. Leonard Smith '74	Plotting packages
Bruce Tow '73	Basic
Warren Montgomery '73	DTSS Executive, Shuffle, On-line Drum and Disk Testers
Christian E. Walker '73	Edit, Basic
Tat-Hung Chan '74	Fortran, Cobol
Thomas S. Harrison '74	GMAP, NMAP, MIX
Dexter C. Kozen '74	Fortran, Filemove
Bruce B. Backa '75	Validation Monitor, Filemove
Cameron W. Jones '75	Basic, Exec, 7MAP
William B. Noyce '75	Simon, Background tape modules
David S. Pearson '75	Catalog, Bakmon, Linker, Dynamo, Execute
Steven E. Poulsen '75	Migrate, APL, Perform
Peter E. Smith '75	Migrate
Brig B. Elliott '76	APL, PL/I, Algol
Harold M. Franklin '76	Exec
Noel S. Kropf '76	Fortran, Forgsim, Chess
William R. Schillhammer III '76	Exec
Robert G. Yasi '76	Gcos Simulator, Bakmon
Jordan M. Young '76	LE700, TCCPL
M. Alex Colvin '77	DDT, Hardware diagnostics
Wayne B. Gray '77	Filemove, Backsys
Thomas G. Tape '77	Tape modules
So Fai Wu '77	Billing
Bennett A. Crocker '78	Tdump, Sysout
Jeffrey W. Dalton '78	Bakmon, Snobol, Lisp
Tyree A. Hilkert '78	Exec, GMAP, Backsys
David E. Jabs '79	Tape modules, Backsys
Edward L. Pepper '79	Simon, Exec
Rufus V. Smith '79	Bsubmrge, Xmonkey
William W. Spademan '79	Recover, Migrate, Mail

they allow users to associate with a file a personalized algorithm for determining permissible accesses. A slave-trap program is a directly executable file which is run by the DTSS Executive before any accesses are granted on the file being opened. The slave-trap program receives information about the job attempting to open the file and, upon termination, informs the DTSS Executive of the accesses to grant on the slave-trapped file.

On-line Mail System

Using the MAIL command, DTSS users can exchange messages. The MAIL system enables a user to receive messages from parts of DTSS (such as the file migration system), as well as from other users. The procedure for sending mail is quite simple and can be done with one command line or on a step-by-step, interactive basis, by entering the MAIL system.

Priority Demonstration Queue Service

Users with special requirements for faster system processing and response may apply to the Office of Instructional and Educational Research for PDQ permission. This feature has been utilized primarily by instructors giving classroom demonstrations using DTSS.

Shared Files

The ability to open files in "shared mode" was introduced in 1976. Shared mode permits two or more users to obtain Read and Write permissions on the *same file* at the *same time*. It is particularly useful for users who want to modify a common data base.

Telenet Communications Network

In September 1975 Dartmouth joined the Telenet Communications network, which permits remote users to gain access to DTSS via a local call in over 100 cities across the U.S. Telenet was developed by the Telenet Communications Corporation and is a packet-switching, common carrier network which operates nationwide. Access to DTSS through Telenet is relatively inexpensive as charges are independent of the user's distance from Dartmouth. Users pay a flat hourly communications charge for Telenet service in addition to the standard DTSS rates for resources consumed.

Operational Improvements

The installation of the new Honeywell 66/40 system necessitated a number of software changes to enable DTSS to take advantage of new hardware features. These included updating the executive system to interface with the new Input-Output Multiplexor (IOM); the new disk units (Honeywell DSS190's, which replaced the previous IBM 2314's); and the new printers, magnetic tapes and other peripheral controllers.

A number of programs, including language processors such as BASIC and COBOL, were modified to use the new hardware's "Extended Instruction Set" (EIS). These instructions are particularly well suited for alphanumeric and textual processing, and resulted in speed improvements of 5:1 and 7:1 in COBOL.

A number of other improvements include a new swapping algorithm, improved diagnostic aids and the ability to dump and load Honeywell's Microprogrammed Peripheral Controllers (MPC) while DTSS is in operation.

Finally, DXPL (Dartmouth XPL) has become widely used as a language for the development of system software. This has resulted in programs which are easier to read and maintain as well as faster to write.

4. APPLICATIONS

Educational and Research Applications

For many faculty members, the computer is an indispensable tool; according to *Computing as a Matter of Course*, 43% of the Dartmouth faculty have used computing for instruction or research. This section summarizes some of the computer-aided research which took place at Dartmouth in 1975-76.

Processing Satellite Data

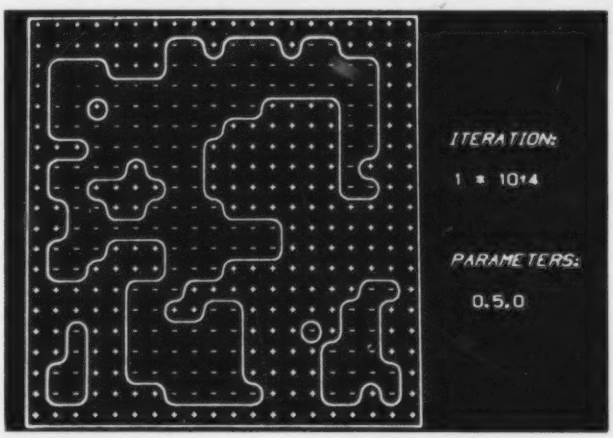
A team of research assistants and graduate students in the Department of Earth Sciences are using DTSS to process satellite data for remote sensing applications. The data are gathered by the LANDSAT systems, recorded digitally, then transmitted to receiving stations on the ground. At the receiving stations the data are stored on magnetic tape for subsequent computer processing. The Dartmouth scientists use FORTRAN software to manipulate the data from their remote terminal, which is connected by telephone to the Goddard Institute for Space Studies in New York, and the results are returned on a high-speed printer.

DTSS allows these earth scientists to store the data in files which can be manipulated interactively, enabling them to perform complex statistical and graphical analyses. Using a Tektronix Graphics Tablet, they digitize "ground truth" data taken from maps, which can then be printed out on a TSP plotter, at any scale or map projection, to overlay onto their computer-generated maps. Their research has wide-ranging geological and geographical implications and uses.

Simulating Probability Theory

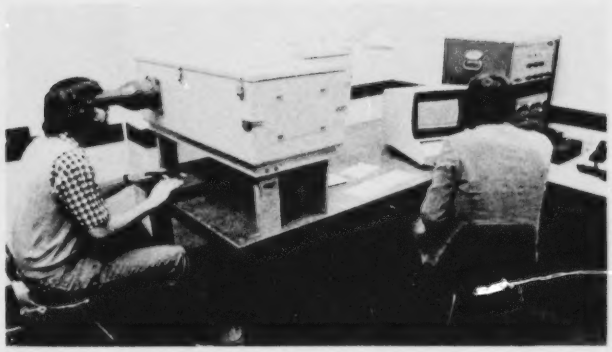
Working under the direction of Professor J. Laurie Snell in an NSF undergraduate research program, students in mathematics are exploring a new area of research in probability theory. This research grew out of work in statistical physics which attempted to understand phenomena of cooperative behavior such as that exhibited in the process of magnetization or in the process of a material's change of state (e.g., from a gaseous to a liquid state). These processes exhibit a critical behavior when such a qualitative change takes place. Probability models developed to study this critical behavior apply also, for example, to voting situations (band wagon effect), social interactions, and spread of disease (contagion occurs or does not occur depending upon a critical value for the probabilities of passing on the disease).

The behavior is simulated using a system of basic units, each in one of a finite number of states. The system changes over time in a probabilistic manner. The probabilities for change are affected by the states of the neighboring units. By varying the basic parameters, the mathematicians are able to see the "critical behavior." Because the system is too complex to study by standard probability methods, they use computer simulation; computer graphics are particularly useful for illustrating how the system behaves over time.



Simulating probability theory on a graphics terminal

47



Setting up for an experiment to study hemispheric differences in visual information processing

Visual Information Processing by the Human Brain

Psychologist John Polich uses DTSS to collect and analyze data for a series of experiments in which he studies the human brain's hemispheric differences in visual information processing. Using a standard tachistoscope connected to DTSS, he displays visual stimuli (such as alphabetic characters) very quickly to a human observer in such a way that the visual information will enter only one hemisphere of his or her brain. Precise measurements are taken of the subject's response times to the various stimuli. From the response times Polich has made various inferences regarding the relative efficacy of each hemisphere for processing a particular form of visual information.

This procedure was repeated for three different experiments requiring the subject to perform increasingly complex tasks. Polich was able to conclude that hemispheric functioning depends on the nature of the task situation rather than on the type of stimulus; processing time appears to be the critical component for elucidating hemispheric differences.

Identifying the X-ray Object Cygnus X-1

Dartmouth astronomers Delo Mook, Forrest Boley and John Cook used DTSS to process spectroscopic data from an x-ray object called Cygnus X-1. The optical wavelength radiation from this object has enabled the identification of Cygnus X-1 as a two-part system, one component of which is probably a black hole. Their recent work has further confirmed this identification and has established certain time-dependent measures of spectral features.

Producing contour maps of the equal-error curves given spontaneous uranium-238 fission tracks, induced uranium-235 tracks, and neutron flux

Fission-Track Dating

Professors Noye Johnson of the Earth Sciences Department and Victor E. McGee of the Amos Tuck School of Business Administration collaborated on an 18-month study of fission-track dating. They developed a statistical model which allows researchers to gain greater understanding of the errors involved in determining the age of crystals. Among the several computer programs developed for this project is one which draws a contour map of the equal-error curves given spontaneous uranium-238 fission tracks, induced uranium-235 tracks, and neutron flux.

Project IMPRESS staff, clockwise: Dave Luchini, Manager; Bruce Backa, Systems Maintenance Programmer; Donna Nadeau, Secretary; and David Lurie '79, student assistant

Project IMPRESS

Project IMPRESS is a data archive and a data analysis package. First funded in 1968 by National Science Foundation, Sloan, and Carnegie grants, its goal has been to maintain an archive of social science data at Dartmouth and facilitate its use in undergraduate teaching and research.

The project currently holds more than 80 studies. These data include information on primitive cultures, presidential elections, demographic and econometric trends. The IMPRESS analysis program provides the student, teacher, or researcher with easy access to the data and quick interactive analysis of significant variables.

While use on campus is heavy, almost half of IMPRESS' 32,000 runs per year come from off-campus users doing research and teaching with their own data and with IMPRESS data.

BARON: Basic Archive for Research on Organizational Networks

Professor Joel Levine, a Dartmouth sociologist, has developed a computer-based system designed to facilitate research into the properties of large-scale social networks. BARON represents his effort to break through the technical difficulties that have impeded substantive analyses of network data. Applied to corporate interlock data, for example, BARON allows rapid and inexpensive access to the data on links among selected groups of corporations.

BARON includes (1) an efficient data management capacity and (2) a nascent data archive. The efficiency of the network data management capacity is based on BARON's "object by relation by object" data structure. The data archive presently includes contemporary data on corporate interlocks involving 797 major U.S. corporations and their 8623 directors plus historical data on corporate interlock data from 1872, 1875, and 1885.

Teaching Logic with a Program

Dartmouth's Philosophy Department is using an interactive program to teach natural deduction to students of introductory logic. BERTIE (named for Bertrand Russell) checks deductions in sentential logic and in quantificational logic (with identity). BERTIE permits the student to enter a problem of his own to work on or to select one of the many problems already stored in the program. In either case, when a student enters a line of a deduction, BERTIE makes sure the formula is well formed and correctly justified. If the student is having difficulty with a problem which BERTIE furnished, BERTIE provides some assistance and even provides a complete deduction for the problem if the student is unable to construct one or would just like to compare his or her solution with the program's.

In performing the functions sketched above, BERTIE can assist in the learning of the techniques of natural deduction in several ways. First, BERTIE will call the student's attention to errors made in constructing sentences. For example, beginners often leave out crucial parentheses; BERTIE will provide the student with immediate feedback when such mistakes

occur. Secondly, the student's attention will be called to errors made in justifying formulas entered. In many homework problems beginners often unknowingly misuse certain rules; BERTIE will immediately, but politely, inform the student of such mistakes.

Finally, BERTIE assists the student in acquiring the strategies and tactics necessary for solving problems in natural deduction. The stored problems are arranged in order of their increasing difficulty and have been carefully selected to illustrate various methods and strategies of natural deduction; a set of hints is provided for each stored problem, and as many lines of a stored solution to the problem as the student needs in order to understand the basic techniques used to solve the problem.

Administrative Applications

Many departments within the College have turned to the computer for help with cumbersome administrative tasks. A few of these applications are highlighted in this section.

Using DTSS to expedite the course changing process at the Registrar's Office

Development Office

During the period July 1973 through July 1976, the Development Office implemented a new Alumni Computer Records System. Accessible via a unique identifier for each alumnus or alumna, this system includes a broad spectrum of data elements, ranging from preferred mailing address, related mailing codes, and alumni activities, through occupational data to current and historical giving.

The large data files are input and controlled directly from the Development Office in Crosby Hall. This decentralized updating affords better data control and better file protection while using to the best advantage the data handling flexibility of the Dartmouth Time-Sharing System. This unique approach places at the disposal of the Development Office almost unlimited options for data extraction and report formatting.

The Alumni Computer Records System serves all Alumni Affairs groups in addition to the Development Office. It was designed and developed with an emphasis on ease of interface with other departments within the College community, in order to enable data transfer from one department to another without the necessity of hard copy. The ultimate aim is a complete cycle from Admissions through the Registrar to Development's Alumni Computer Records for the biographical data as well as interface with the Comptroller and other financial departments for gift data.

Office of the Registrar

The Office of the Registrar uses the Dartmouth Time-Sharing System to expedite a wide variety of functions: verifying eligibility for the degree, recording student course selections, maintaining grade records, preparing statistical reports, tallying faculty elections, and scheduling examinations. The Kiewit computer also plays a significant role as an aid in maintaining information for several College publications and in preparing communications from the Registrar to students and academic departments concerning course offerings, course enrollments, and the students' progress with respect to the major and distributive requirements.

Using programs prepared by the Kiewit staff, the Registrar's Office is able to provide a number of services formerly considered impossible. The

Registrar can, for example, instantly furnish class lists and enrollment data relating to individual courses. In addition, except as the program is overridden to allow for special needs of individual students and faculty members, it is also possible to establish and maintain equal enrollments in the various sections of a course throughout the course-changing process and to make course changes from several terminals, each of which has access to common, up-to-the-moment data on course enrollments, permission requirements, and enrollment limits.

Tuck School

Two offices within the Amos Tuck School of Business Administration have made significant use of time-shared computing to facilitate and enhance their records keeping. Using the data handling capabilities of Project FIND, the Offices of Alumni Affairs and Admissions maintain sophisticated data bases on the students and alumni of Tuck School.

Admissions: Since 1973 the Tuck School Admissions Office has used DTSS to streamline processing some 1400 applicants each year, thus reducing the staff's clerical workload and improving the accuracy and timeliness of the information available to the Director of Admissions. The Admissions Office uses programs which interact with the library program FIND***, a database management system, to produce weekly statistical summaries of applications activity, as well as to generate a variety of annual reports and perform simple clerical tasks. The office has also used the computer to analyze such things as office workload, and recruiting and interviewing policies. Plans are underway to study the behavior of the applicant pool in order to develop some predictive models.

Alumni Affairs: Over the past five years the Office of Alumni Affairs has developed two separate, yet interactive, systems: the Tuck Alumni Records System (TARS) and the Tuck Alumni Giving System (TAGS). TARS contains the names, addresses, and related information on all 5100 living alumni of Tuck School and the Tuck Executive Program; TAGS stores data related to the gift-giving history of all living Tuck alumni.

TARS allows the user to select alumni by specifying any of the attributes associated with each alumnus. This flexibility enables the Alumni Affairs Office to plan and manage creative fund-raising campaigns, as well as reunions and special regional meetings. Working in conjunction with a group of programs which select, edit, and format alumni records for inclusion in the directory, TARS is also used to produce the *Tuck Alumni Directory*. Mass mailings are facilitated by the label printing capabilities of the TARS program. The Tuck Placement Office also uses the TARS system in their recruiting and placement efforts.

The Dartmouth Time-Sharing System is used extensively within the Amos Tuck School of Business Administration. Described here are applications within the office of Alumni Affairs and Admissions. Lower left: Theresa Skarp, Secretary, and Ernest Draper, Assistant Dean for Alumni Affairs; lower right, Natalie Brundred, Secretary, and Roger Muller, Assistant Director of Admissions.

Project FIND

Project FIND (*F*orecasting *I*nstitutional *N*eeds for *D*artmouth) is a management information system developed at Dartmouth over the last four years. FIND is a tool, requiring minimal computer expertise, which can be used to manage private or institutional data bases. Private FIND data bases can be created and managed by any user of the Dartmouth Time-Sharing System. FIND's institutional data bases are maintained for Dartmouth's administrators and faculty members to obtain current information on the college's finances and staff.

FIND users can easily write programs to interact directly with FIND software in order to perform routine tasks of data manipulation. Several models have already been developed which retrieve data from Dartmouth's institutional data bases, including one which produces data for payroll purposes, one which generates reports for budget forecasts and salary equity reviews, and one which produces the official *College Directory*.

Computerized Phototypesetting

A significant step has been taken at Dartmouth in the area of computer-aided text processing. Since 1973 it has been possible to prepare manuscripts for phototypesetting using the Dartmouth Time-Sharing System, thanks to Stephen V. F. Waite of the Office of Academic Computing. He has developed a series of programs which manipulate page layouts and typography by performing all of the functions of a typesetting machine.

Besides being a fast and economical way to produce photocomposed copy, this system affords almost complete control over the appearance of the final product. Because of the advantages of computerized text processing, occurrences of human error are minimized, thus eliminating many of the problems of normal typesetting, which necessitates manual (and redundant) transcription of already carefully prepared copy.

An interesting feature of this system is its ability to simulate the final product during preparatory stages, a feature that permits an author or editor to lay out pages to precise specifications. Page layouts can be checked by viewing a proportional representation of the page on Tektronix terminals. Using codes to represent typographic variations, the system also produces printouts which approximate spacing and show where lines, paragraphs, and pages end; these printouts can be proofread and the files corrected until the copy is letter perfect. Another convenient feature is the system's ability to convert source files from RUNOFF***, a program which produces clear output on a terminal, to the language that operates the typesetter.

Health Care Applications

While DTSS is used extensively by the Dartmouth Medical School and by the Dartmouth-Hitchcock Medical Center, the health care applications reviewed here describe the enlistment of the computer in the battle against cancer.

Tumor Registries

Norris Cotton Cancer Center: The New Hampshire-Vermont Central Tumor Registry collects demographic, diagnostic, treatment and follow-up data on all cancer cases diagnosed after 1972 among residents of the twin state region. A computerized follow-up registry of cancer patients treated at the Mary Hitchcock Memorial Hospital before the Central Registry was established is also maintained. The facilities of the Dartmouth Time-Sharing System are used to process, store and analyze this information.

The Registry program is being developed to have a significant impact on the local cancer problem. Hospitals use Registry services to help meet the requirements for operating cancer programs approved by the American College of Surgeons. The Registry provides a data base for scientific studies of cancer epidemiology and is used to plan and evaluate cancer programs.

Dartmouth-Hitchcock Medical Center: The Dartmouth-Hitchcock Medical Center is participating in a statewide Breast Cancer Network Demonstration Project. As part of the Project, a mammography registry involving 15 hospitals is being maintained in the Norris Cotton Cancer Center. Patient records containing medical, historical and socioeconomic data are input for all women who have had a mammogram and who have consented to have this information made part of the registry. Additional pathological and

treatment data are appended as they become available. The registry is an integral part of the whole Project, whose ultimate goal is to improve the quality of care for the breast cancer patient.

In addition to the mammography registry there is a data file containing information on over 100 women who are currently being treated for breast cancer. Members of the Department of Community Medicine, Department of Psychiatry, and physicians from the Dartmouth-Hitchcock Medical Center are reviewing the data to determine the functional status of this group of patients. The purpose of the Functional Status Survey is to assess the impact of breast cancer on three major aspects of the patient's life: physical functioning, socioeconnomic activity, and psychological functioning. An assessment of how long patients tend to be impaired at different stages of the disease should make it easier for physicians to decide what kinds of rehabilitative efforts are needed and at what point to make them available.

Cancer Treatment

For nearly a decade the Department of Therapeutic Radiology of the Dartmouth-Hitchcock Medical Center has been applying computer technology to clinical radiation oncology (the study of tumors), relying principally on the time-sharing capabilities of the Dartmouth Time-Sharing System and communicating with DTSS via a variety of terminals, including an IMLAC graphics display minicomputer.

Specialized programs allow them to make comprehensive plans for radiotherapy treatment using specific anatomical and density information obtained from a tomographic whole-body scanner. (Tomography refers to techniques for making x-ray pictures of a predetermined plane section of a solid object by blurring out the images of other planes.)

Cancer treatment using DTSS at the Dartmouth-Hitchcock Medical Center

The advantages of computerized radiotherapy include the simultaneous characterization of an external body contour, superior delineation of internal structures, and the ability to calculate density values of the body which will influence treatment. Physical data can also be obtained on-line from treatment machines. Precise measurements for the radiation field are taken using the graphics terminal and DTSS.

5. THE FIRST DECADE

On December 2, 1966, Dartmouth College sponsored a seminar on "The Future of Computers" to commemorate the opening of the Kiewit Computation Center. Noted computer scientists from the United States and abroad met in Hanover to discuss the probable impact of the computer on society, and to dedicate the new building and the new G-635 computer. Ten years later, Dartmouth was host to another major conference, which examined the impact of the computer on society and the real problems which confront mankind as a result of this computerization of our everyday lives. Entitled "Man and the Computer" (from the book of the same name by Dartmouth's president, John G. Kemeny), the conference marked the tenth anniversary of the Kiewit Center. At the anniversary ceremony Dartmouth's new Honeywell 66/40 computer was dedicated to the mission of providing for preeminence and innovation in the field of instructional computing.

It is appropriate at this time to examine the highlights of computing at Dartmouth during the decade which fell between these two historic events.

Instructional Computing at Dartmouth

During this decade probably the most far-reaching effect of Dartmouth's time-shared computing was its impact on instructional computing, at both the secondary and college level. The National Science Foundation contributed heavily to this work through its funding of four major projects: The Secondary School Project, The Regional Network, CONDUIT, and COMPUTe. These successful activities were appropriate descendents of two earlier NSF grants that allowed Dartmouth to develop its first time-sharing system.

The Secondary School Project

This project developed curricular materials to support the use of computers in the teaching of traditional subjects at the secondary level. Indeed, about thirty so-called topic outlines, eight published booklets, and one textbook were produced. More important however were the side effects of the project. In order to prepare curricular materials, terminals had to be installed and teachers trained. With this start, most of the participating secondary schools warmly embraced computing and continued their use of it long after the project ended, either on the Dartmouth machine or on their own mini-time-sharing system.

The two coordinators, John M. Nevison and Jean Danver, were later to influence the course of instructional computing through papers and talks. After one year at Dartmouth, Danver went on to Hewlett-Packard, where she headed the educational marketing group for several years. Both there and at Digital Equipment, the most successful products mimicked the original Dartmouth approach. Based on the thousands of Dartmouth-like systems sold by these vendors, it seems safe to conclude that perhaps millions of students in the United States, and even around the world, have learned computing Dartmouth-style.

The Pilot Regional Network Project

While Dartmouth's involvement with secondary schools has diminished, it is still strongly supporting use by other colleges through various networks. The work at the college level grew mainly from the NSF-supported Regional Network. (The NSF Pilot Regional Network Program in turn grew out of the so-called Pierce Report of the President's Scientific Advisory Committee in 1967. The Pierce Report was instigated in part by Dartmouth's early experiences with time sharing; both John G. Kemeny and Thomas E. Kurtz served on the subcommittee that prepared the report.)

Again, the major purpose of the Regional Network was to promote and explore the use of computers in the teaching of traditional subjects. The term "adjunctive use" was coined to distinguish it from CAI. College level teachers are less dependent on polished text materials; this effort therefore thrived in spite of the lack of suitable texts. Many participating institutions later obtained their own computers. Others have continued to this day using time-sharing services delivered over networks. Of the more than thirty such regional networks supported by the NSF, Dartmouth's was one of a dozen or so that became financially self-sustaining and survived. It is considered by many around the world as *the model* to follow for undergraduate instruction.

Around the early 1970s observers became concerned about the relatively slow growth of instructional computing. Isolated examples, such as at Dartmouth, convincingly suggested that an educational revolution was at hand. Why had it not occurred? Several hypotheses were put forward at the time:

- There are many good computer programs, but moving them from one machine to another is difficult.
- Teachers are reluctant to spend too much effort on computer-related activities because of the lack of professional recognition.
- What are needed are text materials that can supplement existing courses.
- What is needed is editorial and publishing assistance to bring a myriad of partially completed sets of classroom notes to the light of day.

Dartmouth sponsored or participated in four projects aimed at testing these hypotheses:

- Project CONDUIT
- The CCUC Conferences
- Project COEXIST
- Project COMPUTe

Project CONDUIT

CONDUIT began as a project to determine why computers were not being used more in instruction, given that there must be a "rich array of programs" already written and available. Dartmouth and four other universities (North Carolina, Texas, Iowa, Oregon State) participated. After learning that there was, in fact, a shortage of high quality programs, *CONDUIT* carved out as its charge the publication of instructional program sets. This involved locating them, reviewing them, establishing editorial and technical standards, and setting up a distribution system using magnetic tape.

John M. Nevison led Dartmouth's part of the effort, and contributed mainly to the establishment of technical standards and the catalog. CONDUIT is now centralized at the University of Iowa, but Dartmouth continues to contribute materials and to participate in other ways; for instance, Thomas E. Kurtz serves on its Policy Board.

The CCUC Conferences

The first Conference on Computers in the Undergraduate Curriculum was held in 1970 at the University of Iowa. It attracted over 700 speakers and participants, and was supported by the NSF.

The second such conference was held at Dartmouth, and proved to be the largest ever, attracting over 1000 persons. Everyone in the Kiewit Center did something to help, and that conference is remembered by many as an important event.

By 1976 seven such conferences have been held. The proceedings are a gold mine of accounts in all fields showing how computers have been and are being used by faculty in both large and small institutions.

Project COEXIST

Realizing that the higher education community would not accept radical departures from existing textbooks—especially ones using the computer—the NSF commissioned Dartmouth's Mathematics, Physics, and Engineering Departments to produce text materials that could *supplement* existing and standard texts. These supplements would introduce computing in small doses, but without derailing the main direction of the course.

Project COMPUTe

COMPUTe is a National Science Foundation project based at Dartmouth College for the purpose of encouraging the writing and publication of undergraduate course materials featuring student use of computing. A total of $593,421 in grants has been awarded to Dartmouth over a period of six years to provide two months' salary, housing costs, partial travel reimbursement, and various forms of publishing and technical assistance for a total of 31 authors.

One of COMPUTe's principal goals has been to create economic and professional incentives for teachers to write computer oriented material. To this end, permission was received in 1972 to negotiate publishing contracts for manuscripts, and to offer royalties to individual authors upon publication of their material. Moreover, in early 1976 Dartmouth College reached agreement with the David McKay Publishing Company in New York for publication of the texts sponsored by COMPUTe. After final approval of the National Science Foundation, commercial editions of project materials will appear in a moderately priced soft cover series with uniform format and an identifying cover design. In the meantime, COMPUTe continues to print and distribute completed texts.

Twenty-five texts have been supported by COMPUTe during four summer writing sessions. These texts cover a variety of subjects in the broad areas of physics, mathematics, chemistry, environmental studies, psychology, and geography and urban studies. Dartmouth authors have written materials in the fields of geography, mathematics, logic, and psychology.

Pioneers Day

John Kemeny, Thomas Kurtz and a group of former student assistants who contributed significantly to the Dartmouth Time-Sharing System were honored by the American Federation of Information Processing Societies on May 7, 1974. At that time they received the first Annual Pioneers Award, the highest recognition the computer community bestows on a group whose efforts have made an outstanding impact on computer history and technology. The former students who attended the Pioneers Day ceremonies were Michael D. Busch '66, Richard F. Lacey '67, David L. Magill '68, Sidney W. Marshall '65, Ronald W. Martin '67, John S. McGeachie '65, Charles G. Moore, Jr. '65, T. Kevin O'Gorman '64, and Neil Weidenhofer '68.

Tenth Anniversary

On December 2, 1976, the Kiewit Computation Center celebrated its tenth anniversary by holding a three-day symposium entitled "Man and the Computer," and commemorated the occasion with a rededication ceremony at Kiewit.

Symposium

Papers presented at the symposium examined different aspects of the impact of computers upon our everyday lives, including such issues as public policy making, electronic funds transfer, copyright laws and computer abuse. Several speakers reviewed predictions that had been put forth ten years earlier, at a conference held in honor of the dedication of Kiewit.

Dartmouth's president, John G. Kemeny, a co-author of BASIC and a "founding father" of the Dartmouth Time-Sharing System, gave the keynote address. The other speakers were George Glaser, Management Consultant; Donella H. Meadows, Associate Professor of Environmental Studies, Dartmouth College; Frank B. Ryan, Director, House Information Systems, U.S. House of Representatives; Ruth M. Davis, Director, Institute for Computer Sciences and Technology, National Bureau of Standards; James C. Emery, President, EDUCOM; David H.

Ahl, Editor, *Creative Computing*; Willis H. Ware, Vice-Chairman President's Privacy Protection Study Commission; Robert P. Bigelow, Attorney at Law and Editor, *Computer Law and Tax Report*; Donn B. Parker, Senior Information Processing Analyst, Stanford Research Institute; and Dennis L. Meadows, Associate Professor of Engineering Sciences, Thayer School of Engineering, Dartmouth College.

The proceedings of the symposium "Man and the Computer" are available from the Documents and Supplies Office, Kiewit Computation Center, Dartmouth College, Hanover, New Hampshire 03755; telephone (603) 646-2643.

Rededication Ceremony

A ceremony was held on Kiewit's tenth anniversary to rededicate the ten-year-old Building, to dedicate the new Honeywell 66/40 computer, and to commemorate the first decade of computing at Dartmouth. Brief speeches were given by John S. McGeachie, Director, Computing Services; John G. Kemeny, President, Dartmouth College; and Peter Kiewit '22. Excerpts from their remarks follow.

John McGeachie: "Today we celebrate the tenth anniversary of the Kiewit Center, and we honor the generosity of Peter and Evelyn Kiewit, who made possible the construction of this computation center and who also made possible the recent expansion of the Dartmouth Time-Sharing System to meet the growing demands of the institution."

"According to our records, we have trained approximately 100,000 students in the use of the Dartmouth Time-Sharing System, most of them from other schools and colleges. We have logged over four million terminal hours on the Dartmouth System, and we have processed over 37,000,000 programs. I think that must be a record. We are currently running programs at the rate of five million a year."

John Kemeny: "There are really three stages in the growth of Dartmouth Time-Sharing, which you might refer to as its childhood, its youth, and the adult years which are just beginning. As it happens with fond parents, some of your best memories are of childhood. I remember two great moments in the birth of a child: one when for the first time on two terminals at the same time, the computer solved two problems.

Peter Kiewit '22 is presented a ten-year commemorative plaque by Thomas E. Kurtz, Director, Office of Academic Computing (left); and John S. McGeachie, Director, Computing Services (right). President John G. Kemeny is seated in the background.

It was a major breakthrough. The second great moment was when on two terminals at the same time the computer solved two different problems and got the right answer on both of them. That was another breakthrough."

"I want to say thanks to one group whose names do not appear on the plaque. That is the several generations of Dartmouth students without whose ingenuity, whose willingness to work endless hours — not just very late at night, which is the normal time to work, but even early in the morning, which I never understood — their willingness to make contributions because they loved what they were doing, their ability to think up entirely new ideas because they did not know they were new — hadn't been so indoctrinated that they had to follow the path that everyone else said was the right path — and their sheer joy in creating a great work have through many, many generations made today's time-sharing system possible."

6. USE OF DTSS: 1973–1976

Growth in the Use of DTSS

In assessing growth in the use of the Dartmouth Time-Sharing System, we have historically considered several factors: availability of and use of services, and system reliability. System usage is closely related to the variety of services available and to their accessibility. The number of hours the system is available depends upon the operating schedule, the numbers of ports available to users, and the reliability of the system.

Use of Services

Use of DTSS service is measured in terms of several major components of service:

Foreground Services: Measurements of the use of time-sharing services include *terminal connect time*, at various transmission speeds; *central processor time* used, input-output (I/O) *words transferred*, and *words stored* "on-line" (in mass memory).

Background Services: The Background system allows users to run programs without tying up a terminal for the duration of the run. It also provides a simple way for users to obtain "batch processing" — services such as punched-card output, high-speed printer listings, or data transfer to or from magnetic tape. Background services are measured in terms of central processor time used; input-output (I/O) words transferred; cards punched, and lines printed.

GCOS Services: Dartmouth runs Honeywell's General Comprehensive Operating Supervisor (GCOS) for several hours per day. As implemented at Dartmouth, GCOS provides limited, closed-shop, batch-processing services. Services rendered are measured in terms of equivalent 16K central processor seconds used.

"Jobs": In measuring the productivity of the system, we frequently refer to "jobs" run, in either Foreground or Background. A job can be defined as any activity which results in information about processor time and I/O units being printed on the user's terminal. Commands such as OLD, NEW, LIST, SAVE and REPLACE do not cause a "job" to be run; commands such as RUN, EDIT, TEXT, COMPILE, DEBUG, and BACKGROUND do cause a job (or jobs) to run.

User Activity: The number of computer ports used and the frequency and duration of such use are indications of the level of user activity. The level of user activity is measured in terms of *total terminal hours used* — the number of hours users spend actively connected to the system.

TABLE 4

UTILIZATION OF G-635 COMPUTER HARDWARE, 1972–1976

TYPE OF SYSTEM USE	PERCENTAGE OF AVERAGE 24-HOUR PERIOD			
	1972–73	1973–74	1974–75	1975–76
Time Sharing	72.7	71.0	69.4	68.6
GCOS	3.5	5.1	7.5	3.0
Idle Time	3.4	.6	1.0	.8
Housekeeping, File Maintenance	4.4	7.0	8.7	9.3
Hardware Maintenance	3.1	2.1	2.6	3.7
Down Time	.7	.7	1.6	.7
Experimentation and Development	12.2	13.5	9.1	13.9
Total	100.0	100.0	100.0	100.0

TABLE 5

AVAILABILITY OF DTSS
FEBRUARY 1973, 1974, 1975, AND APRIL 1976

	1973	1974	1975	1976
Total Ports Available	171	212	246	237
Hours DTSS Running Per Day	18:11	17:22	16:04	16:19
Total Port Hours Available	3110	3682	3952	3867

Productivity: The productivity of the system in terms of *throughput*, the number of jobs or activities accomplished in a given time, is an important measure of the consumption of computer services. Though system productivity is not as obvious as terminal activity, our daily statistical analyses of system performance allow us to monitor productivity in some detail.

The Session: The basic unit of measurement of the consumption of DTSS services is the user *session*. A *session* can be defined as the time elapsed from the moment a user gains access to the system until he or she terminates the connection. The frequency and duration of sessions per user is a good measure of user *activity*. The central processor resources consumed, I/O transferred, storage created, and "jobs" run per session are good measures of system *productivity*.

Availability of Service

The availability of DTSS service to users, measured in terminal or port hours per day, increased from 3,110 during fiscal 1972-73 to 3,867 in 1976; this represents an increase of about 25% during the 3-year period, or about 8.3% per year. (The rate of growth observed between 1971 and 1973 was in excess of 25% *per year*.)

Table 5 shows the factors contributing to this growth. The total increase was due to an increase in the number of ports available: from 171 in 1973 to 237 in 1976, an increase of nearly 39%.

During this period the hours of scheduled service were decreased to allow for additional preventive maintenance for the aging G-635 hardware; the reduced schedule was continued after delivery of the 66/40 computer, in anticipation of "start-up" hardware problems. The reliability of the hardware diminished slightly between 1973 and 1976.

As a result of the shortened operating schedules and decreased reliability, the average number of hours during which DTSS was available to users decreased from 18 hours and 10 minutes per day during 1973 to 16 hours and 20 minutes per day during 1976, a decrease of about 10% (see Table 5 and Figure 5). The net result of all these factors was an increase of 25% in "port-hours" available to users.

Reliability

A high degree of reliability is essential to users of time-sharing services. To provide an acceptable level of reliability, a time-sharing system must: have a 100-percent-predictable schedule; have a minimum number of interruptions to service; and have the capacity to restore service quickly when an interruption occurs.

Three statistics are maintained at Kiewit to measure the effect of interruptions to service: Percent of Time Up and Mean Time Between Failures (MBTF); the time required to restore service is measured as Mean Time To Repair (MTTR).

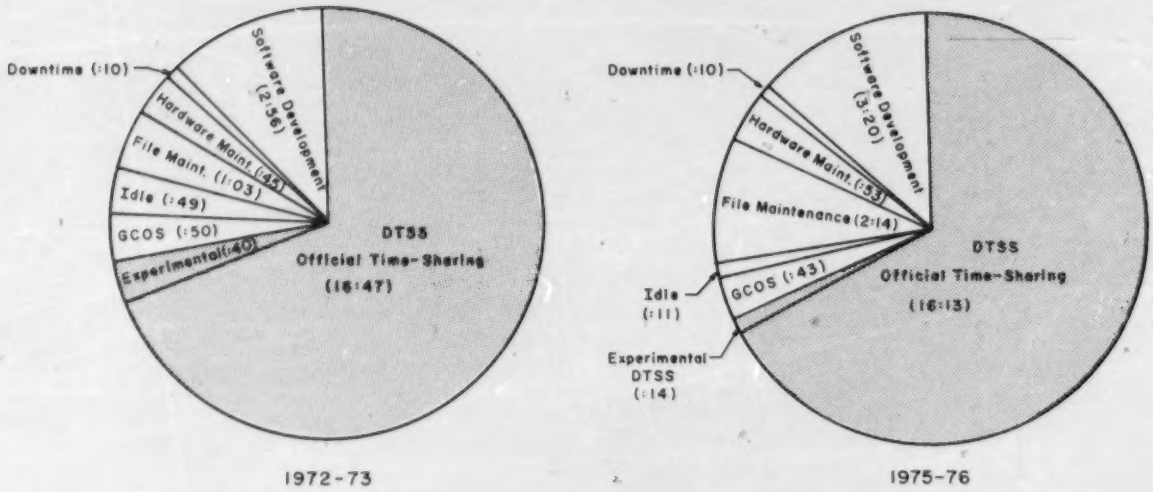
1972-73 to 1975-76

At its best, DTSS provided time-sharing service for 99% of scheduled hours of operation (1972-73); at its worst, the system was available for 97.8% of scheduled hours; by the end of 1975-76, system reliability once again reached 99%.

The system was most reliable during fiscal 1972-73, when it ran, on the average, for more than three days without a failure. At its worst, in 1974-75, DTSS failed nearly twice per day. Mainly due to a special arrangement with Honeywell, whereby additional hardware specialists were provided, the overall reliability of the old G-635 system was increased to 99.34% during the first seven months of fiscal 1975-76. The trends in

FIGURE 5

UTILIZATION OF DTSS COMPUTER HARDWARE
DURING AN AVERAGE 24-HOUR PERIOD



Although "idle" time on the system has been reduced substantially during the past three years, the increased allotment of time to the development of software for the new computer and the vastly increased demand for machine time to maintain user files and other on-line storage have resulted in a slight decrease in the average time available for official time sharing.

TABLE 6

RELIABILITY SUMMARY, 1972 - 1977

	1972-73	1973-74	1974-75	1975-76 635	1975-76 66/40	COMBINED 1975-76	1976 - MAY 1977
Days Scheduled	365	365	365	212	155	367	335
Hours Scheduled	6258	6237	6118	3443	2559	6002	5471
Total Down Time (min.)	3724	4939	8065	1362	2322	3684	3541
Percent of Time Up	99.01	98.68	97.80	99.34	98.49	98.97	98.92
Interruptions to Service	92	138	455	125	113	238	161
Mean Time Between Failures (hr.)	67.3	44.5	13.1	27.3	22.3	25.2	33.6
Mean Time To Repair (min.)	33.0	37.6	16.7	10.3	17.5	15.5	20.8

reliability are shown in Tables 6 and 7 and Figures 6 and 7.

Between 1973 and 1976 the nature of the failures encountered were such that repairs were made more rapidly than during the previous 3-year period, and the overall Mean Time To Repair was reduced from 33 minutes during 1972-73 to just over 15 minutes by 1975-77.

TABLE 7

RELIABILITY OF DARTMOUTH TIME-SHARING SYSTEM, 1972-1977

	1972-73	1973-74	1974-75	1975-76 635	1975-76 66/40	COMBINED 1975-76	1976 - MAY 1977
Hardware Failure							
Number of Interruptions	51.5	63.7	262.2	73.0	42.0	115.0	43.5
Time Lost (min.)	2903.0	3306.7	6142.7	1044.0	1762.0	2806.0	1662.0
Mean Time Between Failures (hr.)	120.3	96.5	22.8	46.9	60.0	52.2	124.4
Mean Time To Repair	46.5	55.0	23.2	13.4	30.9	24.4	32.6
Software Failure							
Number of Interruptions	26.0	52.0	157.7	43.0	34.0	77.0	98.0
Time Lost (min.)	106.5	222.0	495.0	146.0	316.0	462.0	530.0
Mean Time Between Failures (hr.)	238.3	118.4	37.9	79.5	74.1	77.9	55.2
Mean Time To Repair (min.)	3.7	4.0	3.0	3.4	9.0	6.0	5.4
Environment Failure							
Number of Interruptions	3.0	5.0	5.0	3.0	6.0	9.0	6.5
Time Lost (min.)	126.0	889.0	564.0	89.0	40.0	129.0	1080.5
Mean Time Between Failures (hr.)	2065.3	1230.9	1196.7	1140.1	420.0	666.9	832.6
Mean Time To Repair (min.)	31.5	148.2	94.0	29.7	6.7	14.3	135.2
Human Error							
Number of Interruptions	9.0	7.0	17.5	4.0	5.0	9.0	4.0
Time Lost (min.)	523.0	389.0	677.7	79.0	125.0	204.0	230.0
Mean Time Between Failures (hr.)	688.4	879.2	341.9	855.1	504.1	666.9	1353.0
Mean Time To Repair (min.)	40.2	43.2	24.1	15.8	25.0	22.7	38.3
Unknown Cause							
Number of Interruptions	2.5	10.2	12.5	2.0	26.0	28.0	9.0
Time Lost (min.)	66.0	132.0	185.2	4.0	79.0	83.0	38.0
Mean Time Between Failures (hr.)	2478.4	600.5	478.7	1710.1	96.9	214.4	601.3
Mean Time To Repair (min.)	16.7	10.9	14.8	2.0	3.0	2.9	5.1

FIGURE 6

MEAN TIME BETWEEN FAILURES (ALL CAUSES), 1971-1976

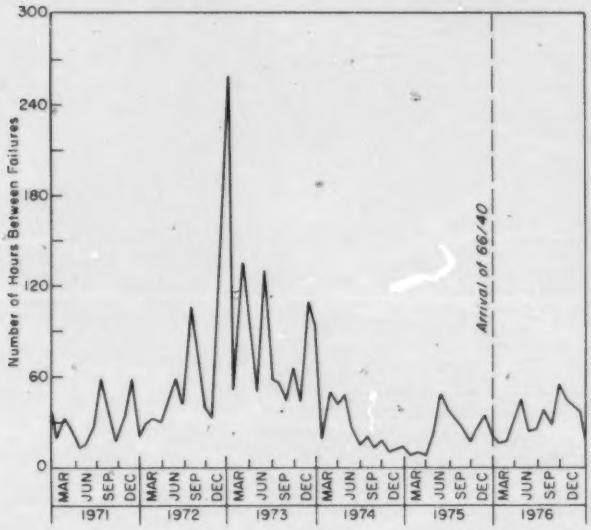


FIGURE 7

NUMBER OF HARDWARE FAILURES PER MONTH, 1971-1976

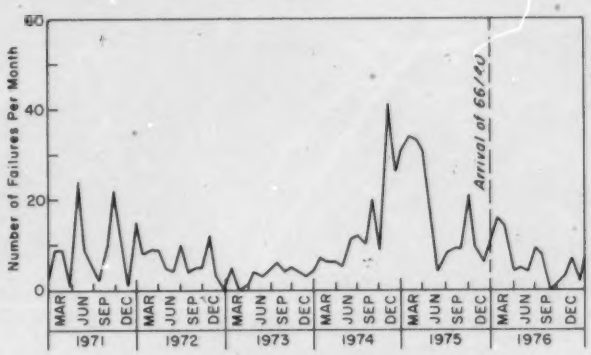
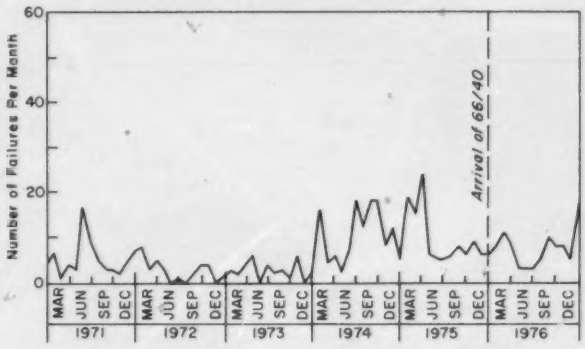


FIGURE 8

NUMBER OF SOFTWARE FAILURES PER MONTH, 1971-1976



Monitoring System Failures

System failures are classified by cause, and are assigned to one of five categories: hardware failures, software failures, environmental failures, human failures, and those of unknown origin.

Hardware failures — Failure of a hardware component of the system. Honeywell's field engineering organization is responsible for minimizing failures caused by the hardware. In 1972-73 a hardware failure occurred, on the average, once every six days of operation and required 46 minutes to repair. In 1974-75, the hardware failed about once each day, and it took more than 23 minutes to repair the equipment. A vigorous effort by Honeywell's field engineers increased the mean time between failures to nearly 48 hours for the G-635 system in the last six months of 1975, and to 60 hours during the first five months of operation of the 66/40 hardware (February through June 1976). These figures are summarized in Figure 7.

Software failures - Failure of any of the many modules of the DTSS software operating system. Such a failure can occur because of an error or "bug" in one of the lines of "code."

During 1972-73 we encountered a software failure once every 12 days and were able to restore service within 4 minutes. In 1974-75 the software operated an average of only 36 hours without a failure but was repaired within 3 minutes. During the first five months of operation of the new system, the mean time between failures was more than 3 days, and improving. There was considerably more development of new software during the latter period; and compounded by the lack of familiarity with the new hardware, this caused the mean time to repair to increase to 9 minutes (see Figure 8).

Environmental failures — Failures of the electrical system or the air conditioning system, caused by internal or external circumstances,

can halt the entire time-sharing system. Although these failures are infrequent, the time to repair them can be lengthy. During the period covered by this report, our record improved considerably, thanks to a sharp decrease in the amount of time lost due to a failures caused by environmental problems.

Human failures — During 1975-76 human errors by an operator or programmer occurred once every 27 days of DTSS operation, and, on the average, service was restored in less than 23 minutes. An unusually high rate of turnover in operations personnel and a lack of familiarity with the new hardware contributed to the slight increase in the frequency of human errors during the period 1974 to 1976.

Unknown or Unclassified Origin — Occasionally, when evidence is not conclusive as to the cause of a failure, it is recorded as "unknown" or "unclassified." Such failures occurred once every 9 days during 1975-76, as compared with one failure every 124 days during 1972-73. "Unknown" failures occurred once every 4 days with the new 66/40 computer, reflecting the unfamiliarity of both hardware and software maintenance personnel with the new equipment. On the positive side, such troubles were diagnosed and fixed in less than 3 minutes in 1975-76 as compared with a mean time to repair of nearly 17 minutes for failures of the same type in 1972-73.

Despite the degradation of service during the saturation period in the last few months of operation of the G-635, Dartmouth takes pride in the overall level of reliability that has been achieved for the large and complex DTSS hardware/software system. We acknowledge the conscientious efforts of the Systems Assurance and Software Development personnel at Kiewit and of the Honeywell Field Engineering organization which have made possible this extraordinary record.

Use of DTSS Services

There have been two significant periods of growth in the use of DTSS services since the *1971-73 Biennial Report* was published. The first occurred during the fiscal year 1973-74, when terminal hours used per day increased by an average of nearly 17%. The second spurt of growth came with the installation and operation of the new Honeywell 66/40 machine, beginning in February 1976.

Table 8 shows sustained growth in terminal hours used per day through September 1974. While there were sporadic surges of growth after that date, due to year-round operation and increased administrative use, in general, September 1974 marks the beginning of system saturation. Subsequently, sporadic growth occurred only during the summer months and between terms, periods which had previously been slack.

From September 1974 through January 1976 there was little growth in the use of system resources, other than system storage. Early 1976 marked the second period of growth: terminal hours used per day between March 1976 and June 30, 1976, increased by 18% as compared with a growth rate of only 2.5% during the first seven months of the fiscal year.

Profile of the User Session

To measure the productivity of an average DTSS user, we examine the user "session." Table 9 presents detailed session statistics, as they were observed each February from 1973 to 1976. Because the February 1976 statistics are based upon use of the 66/40 hardware system, the impact of the increased power of the new system upon the average user's productivity can be observed.

February 1973, 1974 and 1975

The saturation of the G-635 hardware system is evident from the statistics included in Table 9. At first glance, there seems to be growth, as represented by annual increases in terminal hours used per day. The figures for 1973 and 1974 are so close as to indicate comparable productivity. (Jobs per session, jobs per user, and CPU seconds per job are all about equal.) The 17% growth in terminal hours used per day reflects the fact that users remained connected to DTSS for longer periods; terminal connect time per session increased from 26 minutes in 1973 to 30 minutes in 1974. Users spent more time at the terminal in order to accomplish approximately the same amount of work, and thus they were slightly less productive.

TABLE 8

AVERAGE TERMINAL HOURS USED PER DAY, JULY 1972 THROUGH JUNE 1976
PERCENTAGE OF CHANGE OVER PRIOR YEAR

	1972-73	1973-74	%INC %DEC (-)	1974-75	%INC %DEC (-)	1975-76	%INC %DEC (-)
July	541	678	25.3	820	20.9	860	4.9
August	627	851	35.7	859	9.4	890	3.6
September	689	740	7.4	900	21.6	843	-6.3
October	980	1065	8.7	1120	5.2	1174	4.8
November	962	1221	26.9	1152	-5.7	1263	9.6
December	780	913	17.1	908	-.9	930	2.4
January	950	1009	6.2	1070	6.4	1050	-1.9
February	1104	1263	14.4	1312	3.9	1197	-24.6
March	1065	1202	12.9	994	-17.3	1110	11.7
April	896	1082	20.8	1031	-4.7	1238	20.1
May	1038	1186	14.3	1085	-8.5	1359	25.3
June	699	825	18.0	838	1.6	947	13.0
	860	1003	16.6	1007	.4	1072	6.5

TABLE 9

USE OF DTSS FOREGROUND SERVICES
FEBRUARY 1973, 1974, 1975, AND 1976

	1973	1974	1975	1976
Hardware	G-635	G-635	G-635	H66/40
Number of Users	5232	5345	5155	7286
Terminal Hours Used Per Day	1104	1290	1213	1199
CPU Minutes Per Day	785	832	748	971
Sessions Per Day	2522	2563	2742	2665
Sessions Per User Per Month	13.0	13.4	15.4	10.6
Terminal Hours Per User Per Month	5.6	6.8	7.4	4.77
CPU Seconds Per User Per Month	244	261	252	231
CPU Seconds Per Session	12.94	12.41	10.78	14.66
Terminal Minutes Per Session	26.20	30.20	28.74	26.99
Jobs Per Session	6.4	6.5	6.2	6.9
Jobs Per User Per Month	83.0	87.4	96.3	73.4
CPU Seconds Per Job	2.92	2.99	2.62	3.16

By February 1975 the number of users of the system had decreased by about 3%, although the average number of jobs per user increased and the average number of CPU seconds required per job decreased significantly. There was an apparent decrease in the number of large jobs run as the system became saturated. Certainly the users who remained were somewhat less productive than the average user during the preceding two years.

February 1976 (and the H66/40)

The profile of an average terminal session on the 66/40 computer clearly shows the increase in productivity: 36% more CPU seconds were used per session. (According to Honeywell hardware experts, a CPU second on a 66/40 is equal to 1.4 CPU seconds on a G-635. If this estimate is accurate, then the processing power used during an average session increased by over 90%.) The number of jobs accomplished per session increased by more than 11%, and zhe 66.40 CPU seconds used per job in 1976 were 20% more than the G-635 CPU seconds used per job one year earlier. (On an equivalent G-635 CPU-second basis, each job required about 70% more processing power than during the previous February!)

Apparently a considerable amount of frustrated demand for computer services had accumulated during the period of system saturation. To compound the situation the demands which were not being met were demands for sophisticated data retrieval and analysis, which made heavy demands upon I/O and central processor facilities. The growth in the number of users (see Tables 9 and 10) was attributable to significant increases in the number of off-campus network users (especially those using the NERComP network) who made use of the

TABLE 10

NUMBER OF DTSS USERS[a] BY TYPE, 1973-1976

TYPE OF USER	1973[b] PERCENT	1974 NUMBER	1974 PERCENT	1975 NUMBER	1975 PERCENT	1976 NUMBER	1976 PERCENT
On Campus							
Undergraduate	33.6	2889	35.4	2996	35.5	2949	34.9
Graduate	6.0	466	5.7	595	7.1	575	6.8
Faculty	4.2	275	3.4	351	4.2	393	4.6
Administration	1.6	172	2.1	160	1.9	157	1.9
Subtotal	45.4	3802	46.4	4102	48.7	4074	48.2
Off Campus							
High School	14.4	1012	12.4	746	8.8	650	7.7
College							
Dartmouth Network	.....	2641	32.2	2603	30.8	2506	29.7
NERComP	.....	395	4.8	764	9.2	1001	11.8
Montreal	.....	85	1.0	42	.5	12	.1
Telenet Network	.....	0	0	0	0	19	.2
Subtotal	37.1	3121	38.1	3409	40.5	3538	41.8
Government	3.1	46	.6	38	.4	92	1.1
Other	.....	209	2.6	135	1.6	99	1.2
Subtotal	54.6	4,388	53.6	4,328	51.3	4,379	51.8
Total	100.0	8190	100.0	8430	100.0	8453	100.0

[a]Number of users: users who accumulated terminal connect time and used some amount of processing resources during the year.

[b]Percentage only used: users were defined differently in 1973, and the numbers are not comparable.

IMPRESS system and placed high demands upon system resources. A marked increase in the use of the system by Dartmouth College administrators utilizing the sophisticated and resource-consuming FIND database analysis program was a factor in the increased demand for system resources. At the same time the number of high school users, who on the average place light demands on the system, decreased from 1300 in 1973 to just under 700 in 1976.

The On-campus Users, 1973–1976

The availability of time-sharing services on campus increased dramatically thanks to a substantial increase in the number of computer ports which were accessible to on-campus users (see Table 11). In 1973 there were 113 ports (for on-campus use) on the Honeywell 716 communications computer; by 1976 there were 188, an increase of nearly 65%.

Terminal Services

Dartmouth users enjoyed increased access to DTSS with the addition of 56 terminal devices between 1973 and 1976 (a 22% increase). In 1973 there were 253 such devices on campus; by 1976 there were 309. The quality of terminal service also increased substantially as the old Model 33 Teletypes were replaced with faster terminals, operating at 30 characters per second and more, and offering upper- and lowercase characters.

Not only did the number of terminals increase, but also the average number of terminal connect hours logged per terminal per month rose 7%, from 72.2 hours during 1972–73 to 77.3 hours during 1975–76. Total terminal connect hours on campus for 1975–76 were 286,630, an increase of 31% over 1972–73. Less than 3% of this increase occurred during the period September 1974 to January 1976.

Central Processor Services

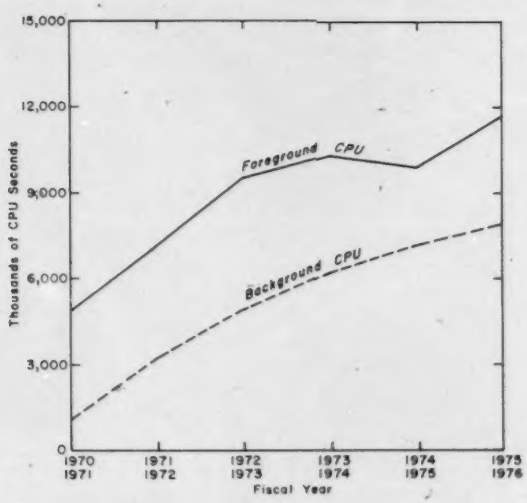
The charts included in this section (Figures 9 and 10) show long-term growth in the use of Foreground and Background central processing services, and illustrate the trends in total use and in the use by user categories.

During the six fiscal years 1970–71 through 1975–76, use of the central processor increased by 230%. Because of the periods of peak demands for Foreground services, use of Foreground central processor services increased only 140% during this period while Background use of the central processor grew 615%.

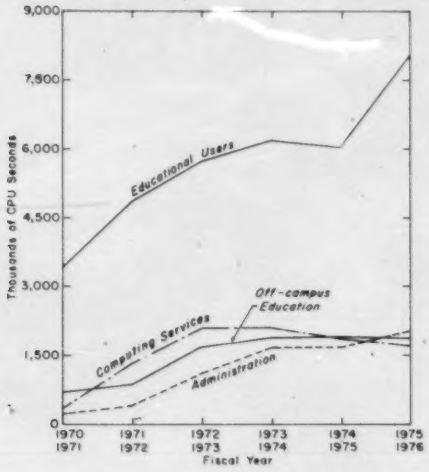
During the first six months of operation of the Honeywell 66/40 computer, an increase of 28% in the use of the central processor occurred. Since the 66/40 operates at an average speed of 1.4 times the G-635, in terms of equivalent G-635 seconds, the users of DTSS consumed 80% more computer power during this initial period of operation than during the previous year.

FIGURE 9

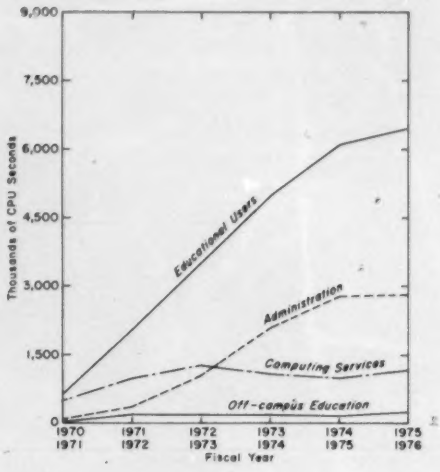
GROWTH IN THE USE OF DTSS SERVICES: FOREGROUND AND BACKGROUND PROCESSING
1970-71 THROUGH 1975-76



FOREGROUND CPU BY CATEGORY OF USER



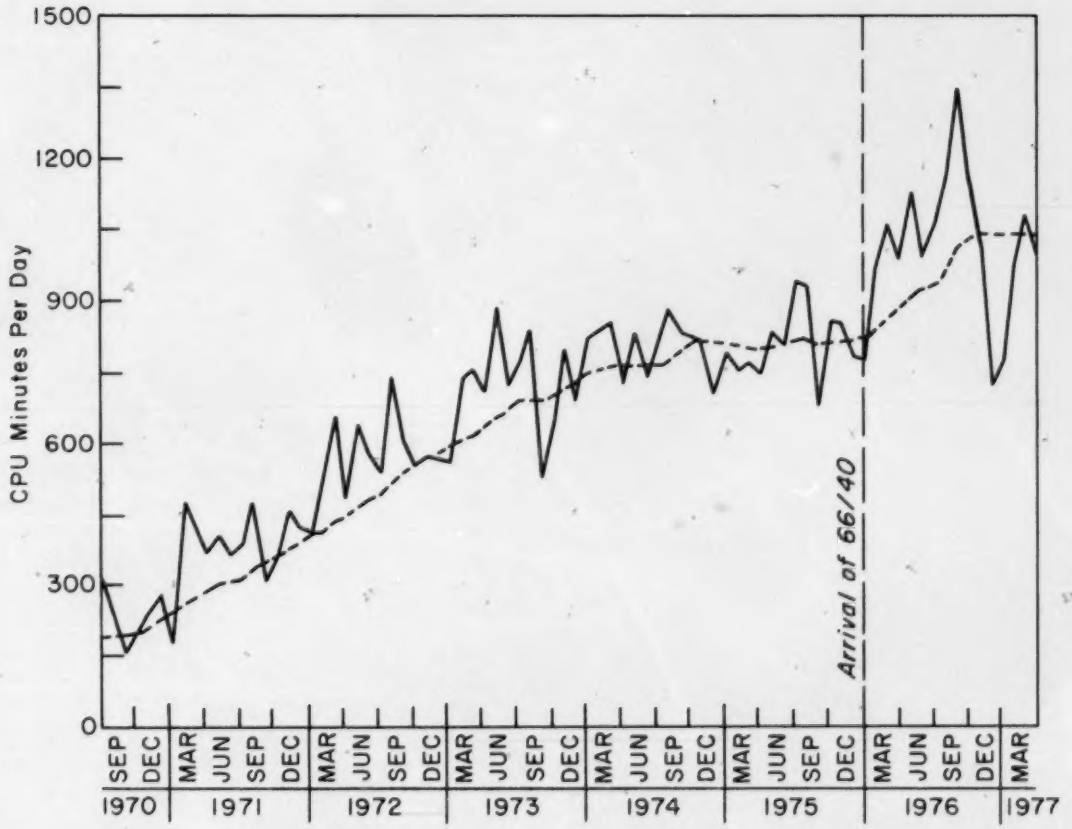
BACKGROUND CPU BY CATEGORY OF USER



The use of Foreground central processor services increased at a substantial rate between fiscal years 1970-71 and 1971-72 (almost 50% per year); however, this growth ceased abruptly between 1973-74 and 1974-75. *Central processor services in Foreground actually decreased* during this period of saturation. The use of Background central processing services increased steadily throughout this five-year period, although the rate of increase declined.

FIGURE 10

GROWTH IN THE USE OF DTSS SERVICES: CPU MINUTES USED PER DAY
JULY 1970-APRIL 1977
(ACTUAL MINUTES USED COMPARED WITH 12-MONTH MOVING AVERAGE)



As shown in Figure 10, there was little growth in central processor services during the period July 1973 to February 1976, until the 66/40 computer began operation in 1976. From fiscal 1970-71 through fiscal 1972-73, Foreground central processor use nearly doubled (up 96%) but increased only 4% from July 1973 through June 1975. The period of saturation continued through February 1976. The months of July 1975 through January 1976 showed no growth over the corresponding months in 1974-75. The 12-month moving average (dotted line) clearly shows a plateau in the growth pattern caused by the saturation of Dartmouth's computing facilities.

TABLE 11

AVAILABILITY AND USE OF SERVICES AT DARTMOUTH

	1972–73	1973–74	1974–75	1975–76
User Category				
Undergraduates	.....	2,889	2,996	2,949
Graduates	.....	466	595	575
Faculty, Staff	.....	275	351	393
Administration	.....	172	160	157
Total	.....	3,802	4,102	4,074
Services Available				
Number of terminals on campus	253	289	287	309
Number of ports available on campus	113	110	183	188
Ratio of terminals to ports	2.24:1	2.63:1	1.57:1	1.64:1
Total hours of DTSS operation per year	6,194	6,154	5,984	5,941
Maximum number of terminal hours available on campus per year	699,922	679,940	1,095,072	1,116,908
Percentage of Total System Services Used by On-Campus Users				
On-campus users as a percent of total users	45.4	46.4	48.7	48.2
Percent of terminal services used by on-campus users	70.8	71.1	73.8	75.3
Percent of CPU services used by on-campus users	87.8	87.2	89.2	88.9
Percent of saved storage used by on-campus users	93.8	92.4	93.0	93.9
Percent of I/O services used by on-campus users	83.1	83.2	85.2	87.9
Use of DTSS by On-campus Users				
Total terminal hours used on campus	219,244	259,715	265,046	286,630
Percent use of available terminal hours	31.0	38.2	26.3	25.6
Average hours used per on-campus terminal per month	72.21	74.88	76.95	77.3
Average number of users per on-campus terminal	16.2	13.2	14.3	13.2
Average hours used per on-campus user per month	4.5	5.7	5.4	5.9
Total CPU hours used on campus	3,487	3,990	4,162	4,841
CPU hours used per on-campus user per year	0.85	1.04	1.01	1.19
Saved storage (1000-word units as of July 1)	59,290	75,350	82,170	85,990
Saved storage per on-campus user (1000-word units) per year	14.5	19.8	20.0	21.1

Saved Storage and I/O

In addition to the large DTSS on-line public Program Library, users have access to their personal catalog of files and programs. On-line saved storage is measured in 1024-word units, and the user is billed on the basis of the *average number of units stored per month.*

Among the most heavily used services of DTSS are data retrieval and file manipulation. The use of these services is measured in "I/O units." An I/O unit is consumed whenever a user requests that data be manipulated or whenever a 512-word block of data is moved. Tens of millions of I/O units are billed to users monthly; in other words, billions of words are transferred annually.

Storage: On July 1, 1973, about 60,000,000 words of data were stored in mass memory. By July 1, 1976, total storage had increased to 86,000,000 words, or by 43%. Since July 1973 about 725,000 words have been added to the disks each month; this has led to an average growth rate of 1.2% per month. The largest increase in storage was in the administrative area, where users accounted for over 60% of on-campus storage in 1975-76, as compared with 26% three years earlier.

Storage conservation procedures, including the automatic migration of unused files to archival tape storage, were implemented during this three-year period. A major and successful effort was made to reduce saved storage in preparation for the transition to the 66/40 system. These conservation procedures contributed significantly to the 25% reduction in the average growth of storage, as measured in additional words saved per month.

I/O: In April 1975 a change was made in the procedure for calculating I/O services consumed by users; consequently, our statistical data on I/O units consumed for the period July 1, 1973, through March 31, 1975, are not comparable to the data collected between April 1975 and June 1976. On an adjusted basis, I/O units billed in July 1973 represented 895,000,000 words transferred. Using the same adjusted units, 860,000,000 words were transferred in January 1976. Although there was some fluctuation during the intervening months, there was no significant growth. Between February and June 1976, an average of 1,240,000,000 words were transferred on the new 66/40 system, representing an increase of 44% over the January figure. This is another example of demands, now being met, which had been frustrated by the saturation of the old DTSS system.

Administrative Use of I/O: The "Crunch Committee Report" states that, "Since March of 1975 administrative use of Background I/O has increased substantially and represents over 40% of all Background I/O." In March 1975 the accounting procedures used to measure I/O operations were changed to include "communication file I/O" and "tape I/O" which result from the use of tapes in Background.

While it is true that the administrators utilize 42% of Background I/O services, the change in accounting procedures is largely responsible for the "substantial growth" in consumption of Background I/O by administrators. Administrative users and Kiewit staff members were the primary users of magnetic tape facilities and so bore a disproportionate share of the increased I/O charges, thus skewing proportional usage figures. Administrative use of Background I/O *actually decreased* between fiscal 1974-75 and 1975-76.

Computing Services Use of I/O: The "Crunch Committee" also observed that "Kiewit almost doubled its share of Foreground I/O in the 3-year period while administrative total share dropped." Again, the change in accounting procedures accounted for the large increase in I/O which occurred in March 1975. The installation of the 66/40 with its eight I/O channels relieved a bottleneck and resulted in substantial growth in the use of I/O by all constituencies. Figure 11, a graph of the trend in use of I/O over the past five years, clearly shows this recent increase, and also demonstrates that the trend reflects a parallel increase in the use of I/O services by on-campus *educational* users (faculty and students). Figure 17 (see Appendix D) shows the long-term growth in the use of the I/O services by category of user.

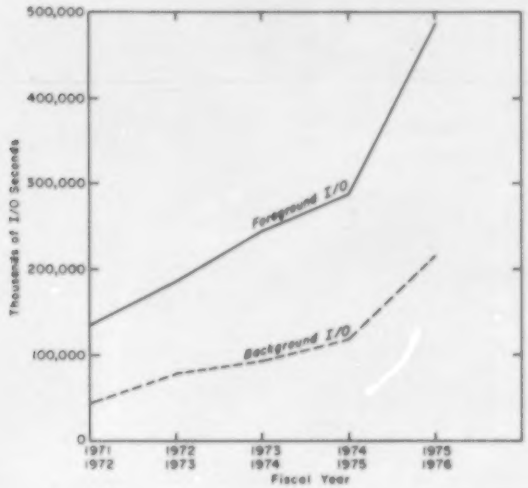
Although both the I/O facilities and the central processor were overtaxed on the G-635 computer, I/O channels in the 66/40 are not yet a scarce commodity.

Background Use of DTSS

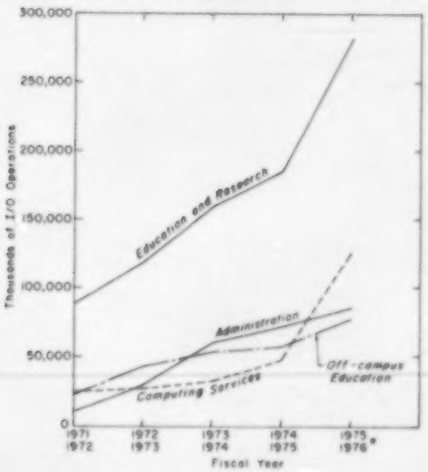
The Background Monitor facilitates remote batch processing. When a job is submitted to Background, the commands are checked and errors noted at that time. Traditional batch

FIGURE 11

GROWTH IN THE USE OF DTSS SERVICES: INPUT/OUTPUT OPERATIONS
1971-72 THROUGH 1975-76



FOREGROUND I/O BY CATEGORY OF USER



BACKGROUND I/O BY CATEGORY OF USER

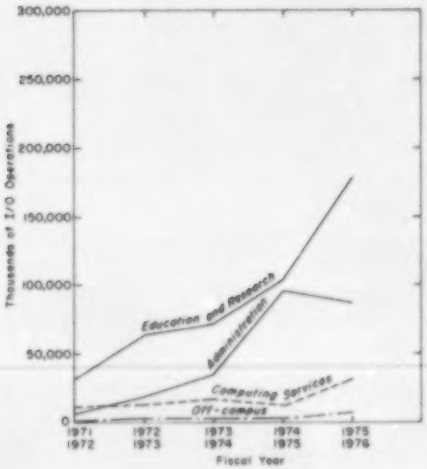


TABLE 12

USE OF BACKGROUND SERVICES
MARCH THROUGH JUNE 1973, 1974, 1975, 1976

AVERAGES	1973	1974	1975	1976
Background users per day	86	93	95	97
Background jobs per day	882	780	754	827
CPU seconds per Background job	17	24	22	29
Jobs per Background user per day	10	9	8	9
CPU seconds per Background user per day	173	203	174	253
Lines printed per month	8,965,800	7,684,512	7,234,265	8,812,396
Cards punched per month	63,209	48,049	29,301	25,681
Lines printed per user per month	3406	2710	2466	2973
Cards punched per user per month	26	17	10	8
Background CPU as percentage of total CPU	32%	40%	35%	40%
Background users as percentage of total users	15%	13%	12%	12%

processing systems do not perform this amount of checking before accepting a job. Having a queue of Background programs waiting to make use of available system resources contributes greatly to the expanded and more efficient use of the central processor for Background.

Table 12 compares the use of Background during the months of March through June, 1973 through 1976. By the spring of 1976, 40% of all central processor use was consumed under the Background Monitor, as compared with 32% in 1973. Although the number of jobs processed per day was slightly less, each job required significantly more central processor time. In 1976 the average job used 46% more CPU resources than were used in 1973.

The use of punched cards continued to decline as terminal-initiated, remote batch processing became the dominant method of noninteractive computing at Dartmouth.

I/O in Background

The graph in Figure 11 shows the growth in the use of input-output services (I/O) under the Background Monitor. By 1975-76, Background I/O represented about 31% of all I/O, as compared with 27% in 1973-74. The apparent surge in the use of Background I/O was due to a change in accounting procedures which primarily affected administrative, Kiewit and research users of Background who made significant use of magnetic tapes.

GCOS Use

For several hours a day during 1975-76, the Honeywell G-635 and 66/40 systems were operated under the vendor's General Comprehensive Operating Supervisor (GCOS). GCOS usage in 1975-76 accounted for approximately 3% of the total hours of system operation (see Table 4). In 1975-76 there were about 184 fewer hours of GCOS operation than in 1972-73. This decrease was attributable partly to (1) the increased use of the DTSS GCOS simulator which operates under the Background Monitor, and (2) the use of a computer at the Massachusetts Institute of Technology for a significant amount of processing by Dartmouth's largest user of GCOS.

Accounting routines for GCOS measure services rendered based on the equivalent central processor seconds used. For example, for each 15 lines printed on the high-speed printer, one second of central processor time is billed. Memory required for the job is also assessed. A job requiring 16K words of main memory, for example, is billed one "second" for each second of run time; a 32K job is billed two "seconds" for each second of run time.

Using these accounting procedures, an estimated 5.9% of all central processor usage during 1975-76 was recorded under GCOS, as compared with 13.7% in 1974-75 and 10.1% in 1973-74.

TABLE 13

USE OF GCOS SERVICES, FISCAL 1973 - 74 THROUGH 1975 - 76

FISCAL 1973 - 74

CPU USED (IN 16K SEC.)	NUMBER OF USERS	PERCENT OF TOTAL USERS	CUMULATIVE USE (IN 16K SEC.)	PERCENT OF TOTAL USE
0 to 2,499	22	64.8	18,404	1.0
2,500 to 4,999	5	14.7	18,544	1.0
5,000 to 9,999	1	2.9	8,496	.5
10,000 to 49,999	5	14.7	78,398	4.2
50,000 to 499,999	0	0	0	0
500,000 and over	1	2.9	1,717,712	93.3
Total	34	100.0	1,841,554	100.0

FISCAL 1974 - 75

CPU USED (IN 16K SEC.)	NUMBER OF USERS	PERCENT OF TOTAL USERS	CUMULATIVE USE (IN 16K SEC.)	PERCENT OF TOTAL USE
0 to 2,499	13	46.4	8739	.3
2,500 to 4,999	1	3.6	4563	.2
5,000 to 9,999	3	10.7	23,953	.9
10,000 to 49,999	8	28.6	175,801	6.5
50,000 to 499,999	2	7.1	199,585	7.4
500,000 and over	1	3.6	2,285,683	84.7
Total	28	100.0	2,698,324	100.0

FISCAL 1975 - 76*

CPU USED (IN 16K SEC.)	NUMBER OF USERS	PERCENT OF TOTAL USERS	CUMULATIVE USE (IN 16K SEC.)	PERCENT OF TOTAL USE
0 to 2,499	7	46.7	5,778	.9
2,500 to 4,999	0	0	0	0
5,000 to 9,999	3	20.0	26,594	4.3
10,000 to 49,999	3	20.0	80,058	13.0
50,000 to 499,999	2	13.3	502,749	81.8
500,000 and over	0	0	0	0
Total	15	100.0	615,179	100.0

*Data for six months only; users were not billed for GCOS use after December 1975.

Table 13 shows the use of GCOS services during the past three fiscal years. There has been a steady decline in the number of GCOS users, from 34 in 1973-74 to 15 in 1975-76. Total use of the GCOS system increased significantly during the first two years of this three-year period; however, for the reasons stated above, during the first six months of 1975-76, the annual rate of use declined significantly.

GCOS remains a one-man system to a large extent; 80 to 95% of the GCOS services consumed during this three-year period were used by one chemistry professor researching the quantum physics of molecules. The requirements of a few individuals for almost exclusive use of the central processor are demands which Dartmouth cannot meet economically. We are therefore encouraging such users to take advantage of the availability of "number-crunching" computer services available through resource-sharing networks such as NERComP. It is our objective to eliminate costly and inefficient use of the 66/40 computer.

Conclusions of the "Crunch Committee"

In summarizing their observations, the "Crunch Committee" reported, "The purpose of examining 'current usage profiles' such as these is to raise the question: Can any user group's usage profile be changed to a 'desired usage profile' in order to make computer response more acceptable at peak load times?" Figures 15 through 20 (see Appendix D) indicate that the different user groups have worked out their own compromises. For example, large Background runs are delayed until late evening. Elsewhere in their report they stated that "Foreground CPU administrative usage and undergraduate usage more or less compensate for or complement each other. This is also true . . . for Foreground I/O."

To a large extent, the complementary usage patterns of the various user constituencies have facilitated efficient use of system resources. The willingness of administrators, Kiewit software development personnel, and faculty researchers to use the Background facilities of DTSS, which make effective use of the system during off-peak hours, and the willingness of students to use the Foreground time-sharing system in the late evening and early morning have facilitated the long-term growth in system productivity despite periods of peak-load saturation.

The trend in the long-term growth of on-campus demand is leveling off, although increases at the rate of 10 to 15% per year seem likely, based upon recent figures. The pent-up demand which accumulated during three years of relative stagnation accounts for a spectacular 33% increase in the use of DTSS resources during fiscal 1976-77, but this extraordinary growth will not be sustained.

Kiewit's objective is to guarantee the equitable and efficient distribution of computer resources. We do foresee a problem in the future with assuring that each group of users will receive a fair share of system resources during *peak* periods. Serious consideration is being given to the implementation of a software mechanism which will partition the system during peak periods so as to guarantee an acceptable level of response to groups of users who are not placing inordinate demands upon the system, while decreasing the response to those whose demands are excessive.

APPENDIX A
HIGHLIGHTS OF *KIEWIT COMMENTS*

Volume 6, Number 9 May 1973

PDP-9 Computer to be moved from Kiewit's basement to the printer output room. Four undergraduates awarded prizes in the annual Computer Art Contest: Christopher Keith, Louis Fernandez, Judith Glovsky and Alan Glovsky. Live display of computer art at the Hopkins Center. Summer Term lecture series announced. New version of FORTRAN implemented. Use of Fetch permission in BASIC expanded. GECOS replaced by GCOS. String programs added to BASIC TEACH package.

Volume 6, Number 10 June-July 1973

Administrative data processing programs sought. John G. Kemeny Computing Prize Winners announced: Warren G. Montgomery, Nicholas Simonelli, Stephen Toll, Cameron Jones, Philip Koch, and Tat-Hung Chan. New rates announced. Background WAIT command described. New DYNAMO system available. System storage problems explained. Dartmouth well represented at annual Conference on Computers in the Undergraduate Curricula. OLD command expanded to retrieve copies of files saved with Public or Fetch permission from another user number. Background tape system updated.

Volume 6, Number 11 August 1973

Fall Term lecture series announced. File name conventions to be changed. System DYNAMO updated. Copying multiple files in Background announced. Preference command (for storage) added. Statistics library programs revised.

Volume 7, Number 1 September 1973

BASIC improved. Dartmouth participated in ACM Computer Chess Championship.

Volume 7, Number 2 October 1973

Acquisition of fourth IBM-2314 disk storage device approved. Members of Council on Computing listed. Project CONDUIT described. File name conventions changed. Access to DTSS from remote locations via direct lines. New printing format inaugurated for *Comments*.

Volume 7, Number 3 November 1973

File purging policies undergoing review. Record for number of simultaneous users broken five times in October; the successive records were 140, 142, 143, 146 and 150 simultaneous users. Fourth IBM-2314 disk unit delivered. Terminal room alterations nearly completed.

Volume 7, Number 4 December 1973

Installation of additional ports delayed. File purging policy revised. Plans for using additional disk storage discussed. Record for number of simultaneous users broken five times in November; the records were 151, 152, 154, 155 and 159. Holiday schedule publicized. Winter Term lectures scheduled. Winter Term IMPRESS lectures announced. Speakers scheduled for Instructional Computing Conference. DXPL language added. FORTRAN improved. DTSS documentation rearranged by breaking down *System Programmers Reference Manual* into separate technical memoranda.

Volume 7, Number 5 January 1974

Fourth disk unit ready for service. Coupler for 716 communications computers tested.

Volume 7, Number 6 February 1974

Telephone number set up for user assistance. On-line consulting program available on an experimental basis. Consulting office established. Experiment undertaken to mail printer listings to on-campus users. Computing contests announced. Document distribution policy revised. New version of MAILSORT*** implemented. Background STATUS command added. FORTRAN INPUT statement changed. Record number of simultaneous users serviced, with 160 signed on.

Volume 7, Number 7 March 1974

716 communications computer became operational. New sign-on procedure for high-speed terminals announced. Talks on programming techniques for efficient use of DTSS offered. System CROSREF improved. Simple Monitor ENTER command added. Record for number of simultaneous users increased to 176.

Volume 7, Number 8 April 1974

Total number of ports and 30 character-per-second lines increased. Express service to be added to Background.

Volume 7, Number 9 May 1974

DTSS celebrated tenth anniversary at NCC conference. John G. Kemeny Computing Prize awarded to William Noyce, William Roy, Richard San Souci, Robert Piela, Bruce Backa and Dexter Kozen. Computing art contest won by Eric Batson. Talks scheduled for Summer Term.

Volume 7, Number 10 June 1974

Revisions to BASIC under discussion. New rates announced. REPLACE and SAVE commands enriched. Literary texts available in machine-readable form. *Creative Computing* edited by Kent Morton.

Volume 7, Number 11 July 1974

Graphical instructions proposed as extension to BASIC. Dartmouth second in Canadian chess championships. Seven summer projects supported by Project COMPUTe. Teaching programs offered in physics and biology. Problems with large jobs discussed. HELP command added. Port numbers changed.

Volume 7, Number 12 August 1974

John Schofield hired to direct User Services. Report on progress of 716 communications computers. Fall Term lecture series announced. File accesses simplified. Procedural change for mailing printer listings.

Volume 8, Number 1 September 1974

Sources of assistance listed. CALCULATE command added. Express queue added to Background.

Volume 8, Number 2 October 1974

Purchase of additional core storage announced. Conference held on graphics in BASIC. Specification of file accesses simplified. Background changes announced. Indexing and concordancing package for texts offered. 179 simultaneous users.

Volume 8, Number 3 November 1974

Holiday schedule announced. Priority service for classroom demonstrations offered. Additional core storage delivered and operating. Dartmouth participated in NCC computer chess tournament. Bridge programmers solicited.

Volume 8, Number 4 December 1974

User Services offices changed. Winter Term talks announced. METRO-APEX workshop planned. Library use being measured.

Volume 8, Number 5 January 1975

Time sharing schedule revised. On-campus terminal clusters listed. Record number of simultaneous users increased to 182.

Volume 8, Number 6 February 1975

Access to DTSS changes explained. Two computing contests publicized. Two computing conferences announced. String Editor enhancements described. 189 simultaneous users.

Volume 8, Number 7 March 1975

NSF grant awarded to Dartmouth College for development of a national standard syntax for graphical operations in BASIC. Spring Term lectures on computing publicized. Rate schedule adjusted.

Volume 8, Number 8 April 1975

Disk storage subsystem installed to replace magnetic drums. Changes and enrichments in Background listed, including introduction of FORGSIM. File migration and recovery system implemented. All on-campus lines converted to variable speed, dial-4 lines.

Volume 8, Number 9 May 1975

Conversion to hierarchical file system and automatic file migration announced. Number of

simultaneous off-campus users restricted. Art contest winners listed: James H. Browning, Robert B. Clyman, M. Lynne Brooks, and Kevin W. Cohan. How to display structure of BASIC programs explained. Creation of BASICLIB*** and attendant reorganization of the program library announced.

Volume 8, Number 10 June 1975

John G. Kemeny Computing Prize awarded to Steven E. Poulsen, Dave S. Pearson, and Cameron W. Jones. User numbers and permissions to be reviewed. New rates announced. Lectures on programming style offered. Improvements made to ALGOL, LISP, and DXPL. New version of IMPRESS implemented.

Volume 8, Number 11 July 1975

Restructuring of computing management functions announced. Two Datanet-30 communications computers departed. Structured programming seminar scheduled.

Volume 8, Number 12 August 1975

Survey of instructional computing summarized. BASIC standardization efforts reviewed. Documentation distribution policy changed. Enhancements to Project IMPRESS described. Index to Volume 8 listed.

Volume 9, Number 1 September 1975

New members of community welcomed. Fall computing courses described. Sources of assistance at Kiewit listed. File migration system reviewed. Computing code of ethics explained.

Volume 9, Number 2 October 1975

Recent improvements to system languages described. File name conventions standardized. Upcoming conferences and professional meetings publicized. Who's who in Computing Services listed.

Volume 9, Number 3 November 1975

Dartmouth participated in prototype demonstration of EDUNET. Progress to date reported for file migration and recovery. Who's who in Office of Academic Computing listed.

Volume 9, Number 4 December 1975

Purchase of new computer approved by Board of Trustees. $500,000 gift from Peter Kiewit ('22) announced. Honeywell 66/40 computer described. Results of 635-66/40 benchmark reported. Conversion schedule publicized. 191 simultaneous users

Volume 9, Number 5 January 1976

Massive file migration performed to make room for new computer. 1976 computing contests announced. Conference on Instructional Computing planned. Winter Term computing courses described. Enhancements to Project IMPRESS explained.

Volume 9, Number 6 February 1976

Standardization proposed for on-campus terminals; five models selected. Sixteen cities now served by Telenet network. Agenda for Conference on Instructional Computing announced. Dartmouth signed agreement to purchase one hundred LA36 DECwriter II terminals. NSF support renewed for Project COMPUTe.

Volume 9, Number 7 March 1976

Progress reported on conversion to new Honeywell 66/40 computer system.

Volume 9, Number 8 April 1976

Two computer-related conferences held at Dartmouth. User-initiated file migration implemented. DECwriter terminals delivered and installation underway.

Volume 9, Number 9 May 1976

Grant awarded to Dartmouth to develop computer-based visual retrieval system.

Volume 9, Number 10 June 1976

Computer art prizes awarded to Nicholas M. Schneider, Paul J. Asente, Eric R. Smith, and M. Lynne Brooks. John G. Kemeny Prize in Computing won by Richard Green and Peter Hirshberg. Summer term computing lectures announced. Production of *Kiewit Comments* described.

Volume 9, Number 11 July 1976

Improvements made to swapping algorithm and BASIC Run-time Package. One-year progress report given for file migration and recovery system. Use of MAIL files explained.

Volume 9, Number 12 August 1976

New members of Computing Services introduced. Progress to date reported on system conversion. Reconfiguration into symmetric duplex system announced. Users warned about upcoming disappearance of SUBSLIB*** and MSUBSLIB***. Public terminal clusters and their facilities listed. Index to Volume 9 included.

APPENDIX B
KIEWIT COMPUTATION CENTER STAFF, AS OF JANUARY 1, 1977

COMPUTING SERVICES

Director	John S. McGeachie

ADMINISTRATION

Assistant Director	Thomas E. Byrne
Assistant Director (Regional Activities)	Eugene A. Fucci
Executive Secretary	Linda S. Maynard
Secretary	Marie C. Stebbins
	Noel S. Ricker
Bookkeeper	Merylene G. Morse
Document Clerk	Diona A. Randall
Editor	Christine W. Thompson

TELECOMMUNICATIONS

Assistant Director	Eugene A. Fucci
Administrative Assistant	Robert W. Gunn
Repairman	Samuel B. Karumba
Electronics Technician	James S. Baker

SOFTWARE DEVELOPMENT

Assistant Director	Stanley D. Dunten
Faculty Associate	Stephen J. Garland
Senior Programmer	Philip D. Koch
	William B. Noyce
	Brigham B. Elliott, Jr.

SYSTEMS ASSURANCE/OPERATIONS

Assistant Director	William M. P. Taylor
System Support Manager	David E. Heller
System Software Librarian	Betsy D. Rubner
Operations Manager	Henry R. Schramm
Senior Operator	Albert C. Norwalk
Operators	Richard M. Joyce
	Alan Kerr
	Gary L. Turner
	Ichao Wei

USER SERVICES

Assistant Director	Arlene S. Larsen
Administrative Assistant-Validations	Nancy O. Broadhead
Program Librarian	Warren D. Belding
Student Program Librarian	Michael S. Sulaver
Technical User Consultant	Steven D. Ligett

DATA PROCESSING OPERATIONS

Assistant Director	Robert R. Costello
Data Processing Coordinator	Roger W. Martin
Operators	Elizabeth A. Benham
	Janet D. Goodhue
	Margaret A. Hannah

ADMINISTRATIVE APPLICATIONS

Assistant Director	Jacqueline W. Cantlin
Information Systems Manager	Michael R. Vitale
User Services Administrator-Project FIND	Nancy L. Karp
Programmer, Project FIND	Frank J. Hoose, Jr.
Program Analysts	L. Lois Marler
	James E. Gunn
	Francis B. Jordan
	James S. Spencer
Programmer	Anya Achtenberg
Secretary	Corinne Stiles

OFFICE OF ACADEMIC COMPUTING

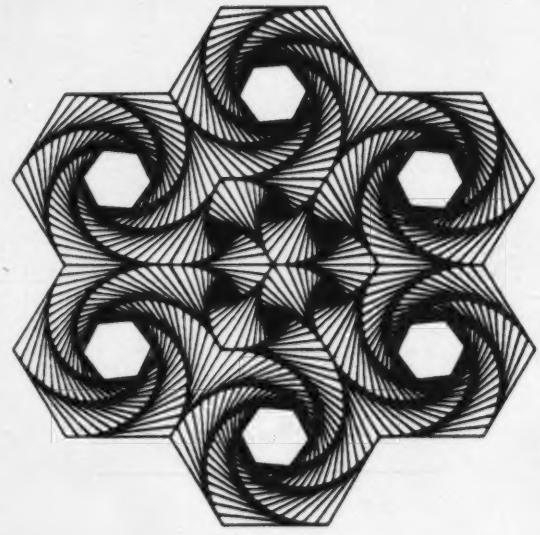
Director	Thomas E. Kurtz
Assistant Director	Arthur W. Luehrmann
Supervisor, Project LIBR!	Stephen V. F. Waite
Assistant Director, Project COMPUTe	A. Kent Morton
Administrative Assistant	Cynthia L. Garvey
Secretary	Paula A. Donovan
	Linda C. Loux

The following people were employed at the Kiewit Computation Center for some portion of the period 1973-1976. Thomas E. Kurtz, Director of the Kiewit Computation Center; Charles D. Harlowe, Assistant Director (Systems Assurance); John E. Schofield, Assistant Director (User Services); Larry R. Harris, Faculty Associate; James M. Hansen, Manager, Telecommunications; Leonard I. Cohen, Business Manager; David Chapin, Manager, Project FIND; John M. Nevison, Manager, Project CONDUIT; Cynthia B. Lesker, Administrator of User Services, Project FIND; Virginia C. Handy, Associate Editor, Documentation; Jane-Anne Dalton, Documents Production Supervisor; Diane G. Mather and Teresa J. Oden, Technical Writers; Josie K. Claiborne, Program Librarian; Walter Fifield and Christopher G. Hoogendyk, Programmers; Roger C. Joyce, Systems Maintenance Programmer; Mary Cartwright-Smith and Peggy Olsen, Administrative Assistants, Project COMPUTe; Karen D. Hurd, Documents Clerk; Judith Stevens, Bookkeeper; Sidney Cushman, Mark Hagen, Michael W. Hebb, and Carl Nelson, Operators; Jean Maier and Lyn Rice, Technical Secretaries; Andrew D'Amico, Frank Smith, and David Watson, Documents Assistants.

APPENDIX C
COMPUTING CONTEST WINNERS

Every year Dartmouth challenges its students to compete in two computing contests; one is the Annual Computer Art Contest and the second is the John G. Kemeny Prize in Computing. To qualify for the art contest, entries must have been prepared using the Dartmouth Time-Sharing System. Students are able to use a number of devices to create their designs, including any printing terminal, any line-printer, Tektronix graphics terminals, and the CalComp, TDI, TSP or Hewlett-Packard plotters. Students competing for the John G. Kemeny Prize in Computing must have developed their project using the Dartmouth Time-Sharing System. Entries are judged on the basis of significance and relevance of the program; the quality of its design and organization; the elegance of its programming technique and style; clarity of the comments and program statements; and the completeness and quality of its written documentation.

Since 1974 the prize winners and their entries have been as follows:



Computer Art Contest

1974	Eric Batson '75	"Dragons"
1975	James H. Browning '78	"WHE"
	Robert B. Clyman '77	"BLOSSOM"
	James H. Browning '78	untitled
	M. Lynne Brooks '76	"PONIES"
	[1]Kevin Cohan '78	untitled
	[1]M. Lynne Brooks '76	"OWLS"
1976	Nicholas M. Schneider '79	"AWE"
	Paul J. Asente '79	"CONQUEST"
	Eric R. Smith '77	"Cactus Flower"
	[1]M. Lynne Brooks '76	"CIRSQR"

[1]Honorable mention

John G. Kemeny Prize in Computing

1974	*Applications*	
	[2]William B. Noyce '75	"N3HID"
	[2]William S. Roy '75	"3HID"
	[1]Richard P. Sans Souci '76	"ZMAT"
	[1]Robert C. Piela '76	"ION"
	Systems	
	Bruce R. Backa '75 and Dexter C. Kozen '74	"FILEMOVE"
1975	Steven E. Poulsen '75	RECOVER, URECOVER
	David S. Pearson '75 and Cameron W. Jones '75	NOVA XPL
1976	Richard Green '75	"XTALK"
	Peter Hirshberg '78	"AUTOPIX"

[1]Honorable mention
[2]Tied

APPENDIX D
USAGE STATISTICS

The following figures and tables document the long-term trends in the use of DTSS; reveal daily, weekly, and annual patterns of use; describe the nature of the demands placed upon the DTSS hardware and characterize the several categories of users.

FIGURE 12

RELATIVE DEMAND FOR COMPUTER RESOURCES
BY DIFFERENT USER CATEGORIES

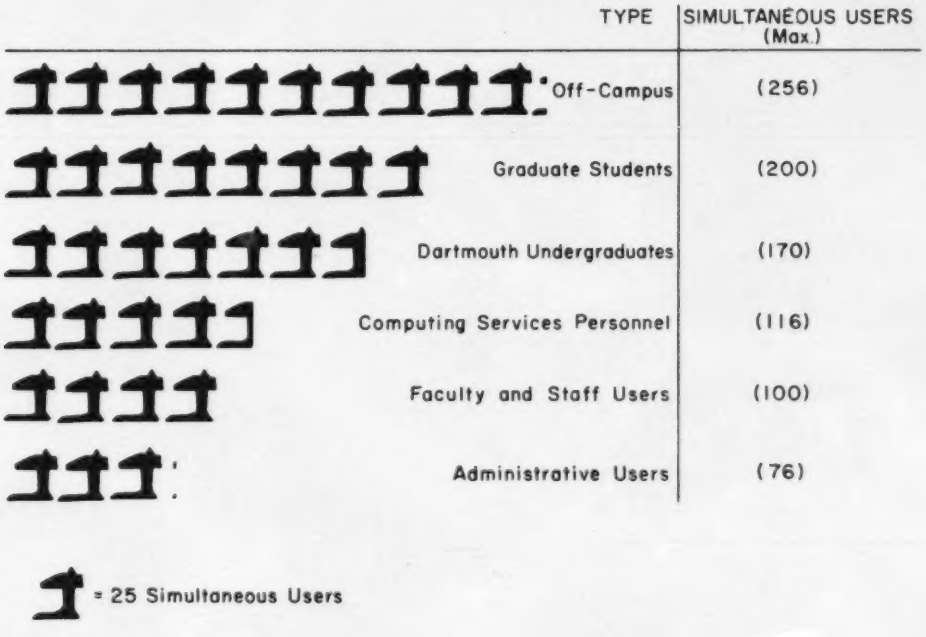
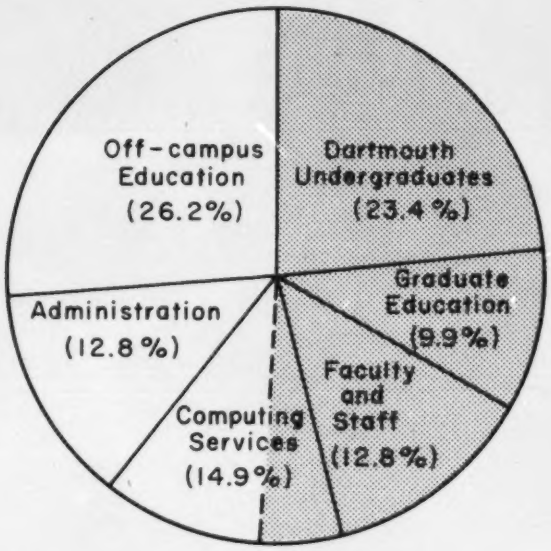


Figure 12 presents another view of the relative demands upon DTSS by the several categories of users. Assuming that the system could handle a maximum of 256 of the least demanding (off-campus) users simultaneously, Figure 12 shows how many users in each category would be required in order to place an equivalent load on system resources; this graph compares the relative demands of the different user categories.

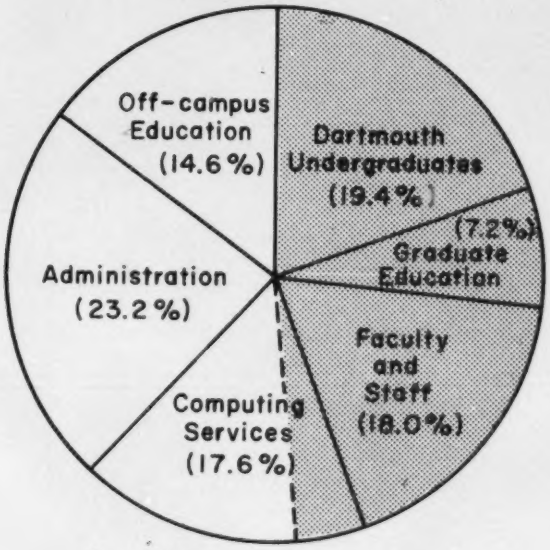
FIGURE 13

DISTRIBUTION OF USERS, FISCAL 1975-76
BY FREQUENCY OF USE VS. INTENSITY OF USE

TERMINAL HOURS BY CATEGORY OF USER



SYSTEM RESOURCES BY CATEGORY OF USER



The pie charts shown in Figure 13 are based upon actual billing statistics for fiscal 1975-76. The one on the left shows the proportion of terminal hours consumed by major categories of users. The one on the right shows the proportion of system resources consumed by each group during the year. Based upon their larger numbers and their relatively small consumption of resources, off-campus users are clearly the "lightest" users of the system, and administrative users are the "heaviest." One administrative user consumes roughly as many resources as 2.3 undergraduates.

Overall, this annual pattern follows the pattern exhibited during peak periods as indicated in Table 15. Educational users (shaded area of the pie chart, Figure 13) account for half of all system resources used; administrative and Kiewit users consume about 30%, and off-campus users account for the remaining system resources used.

FIGURE 14

AVERAGE NUMBER OF SIMULTANEOUS USERS
BY TIME OF DAY AND BY DAY OF WEEK

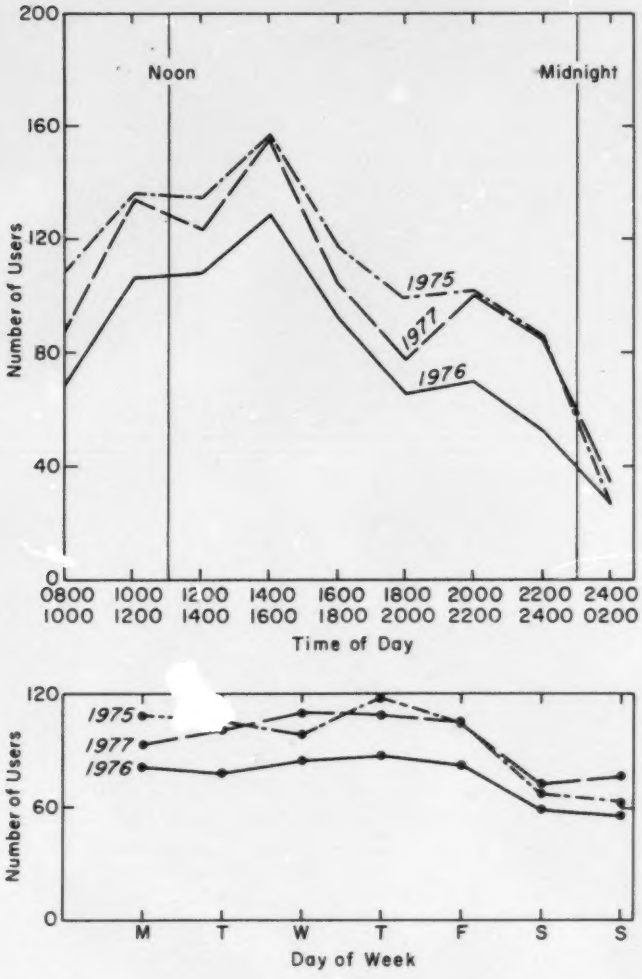


Figure 14 is a graph of the usage patterns for 1975, 1976, and 1977, and plots the number of simultaneous users by time of day and day of week. The impact of administrative users is reflected in the strong 9-to-5 pattern shown in the upper (hourly) chart. Their influence is also visible in the lower (daily) chart, where the Monday-to-Friday pattern reflects lighter use at the beginning of the week and consistently heavy use from mid-week through Friday.

FIGURE 15

PERCENTAGE OF CENTRAL PROCESSOR USED
BY TIME OF DAY AND BY DAY OF WEEK

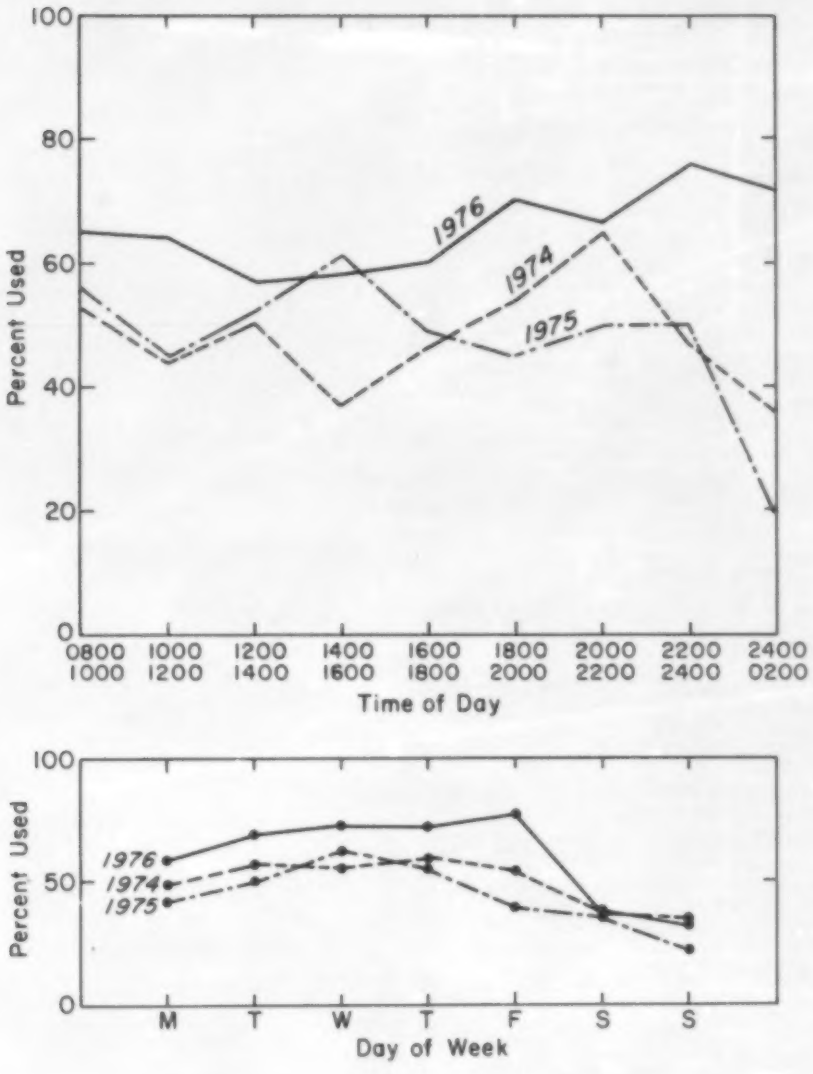


Figure 15 shows the percentage of central processor use by hours of the day and by days of the week. These figures were gathered during the last week in May in 1974, 1975, and 1976. The hourly pattern exhibits a consistently high level of utilization throughout the day; this reflects the complementary usage habits of the various constituencies within the user community. The weekly trend shows increasing demand for central processor resources as the week progresses, with demand peaking on Friday.

TABLE 14

TERMINAL USE BY TIME OF DAY AND BY CATEGORY OF USER

USER GROUP	10–11 a.m.	2–3 p.m.	7–8 p.m.	11–12 p.m.	TOTAL DAY
Percent of day's terminal hours used	8.9%	10.4%	5.7%	2.3%	100%
Educational Users					
Faculty	15.9	12.8	3.9	3.4	11.0
Undergraduates	12.0	22.0	30.8	34.1	19.8
Graduates	8.4	9.7	19.1	25.5	13.2
Other educational users	3.5	3.5	5.7	5.0	3.6
Subtotal	39.8	48.0	59.5	68.0	47.6
Noneducational Users					
Administration	24.9	18.8	3.2	0.0	16.4
Computing Services	8.9	8.0	7.8	22.6	10.4
Subtotal	33.8	26.8	11.0	22.6	26.8
Off-campus Users	26.4	25.2	29.5	9.4	25.6
Total	100.0	100.0	100.0	100.0	100.0

TABLE 15

CENTRAL PROCESSOR RESOURCES CONSUMED
BY TIME OF DAY AND BY CATEGORY OF USER

USER GROUP	10–11 a.m.	2–3 p.m.	7–8 p.m.	11–12 p.m.	AVERAGE FOR YEAR
Percent of daily CPU used during this 2-hour period	9.0%	6.7%	6.8%	5.6%	.....
Educational Users					
Faculty	9.6	12.3	1.5	1.2	8.4
Undergraduates	7.4	21.2	34.4	10.1	15.8
Graduates	14.3	18.3	25.3	52.8	27.8
Other educational users	10.7	4.6	9.7	27.7	7.0
Subtotal	41.5	56.4	70.8	91.8	59.0
Noneducational Users					
Administration	24.6	23.0	14.4	0.0	17.9
Computing Services	15.2	4.8	3.1	6.0	7.6
Subtotal	39.8	27.8	17.5	6.0	25.5
Off-campus Users	18.7	15.8	11.7	2.3	15.5
Tota.	100.0	100.0	100.0	100.0	100.0

FIGURE 16

TERMINAL USE BY TIME OF DAY
AND BY CATEGORY OF USER

FIGURE 17

USE OF INPUT/OUTPUT OPERATIONS IN FOREGROUND

FIGURE 18

USE OF CENTRAL PROCESSOR IN FOREGROUND
BY CATEGORY OF USER, MAY 27, 1976

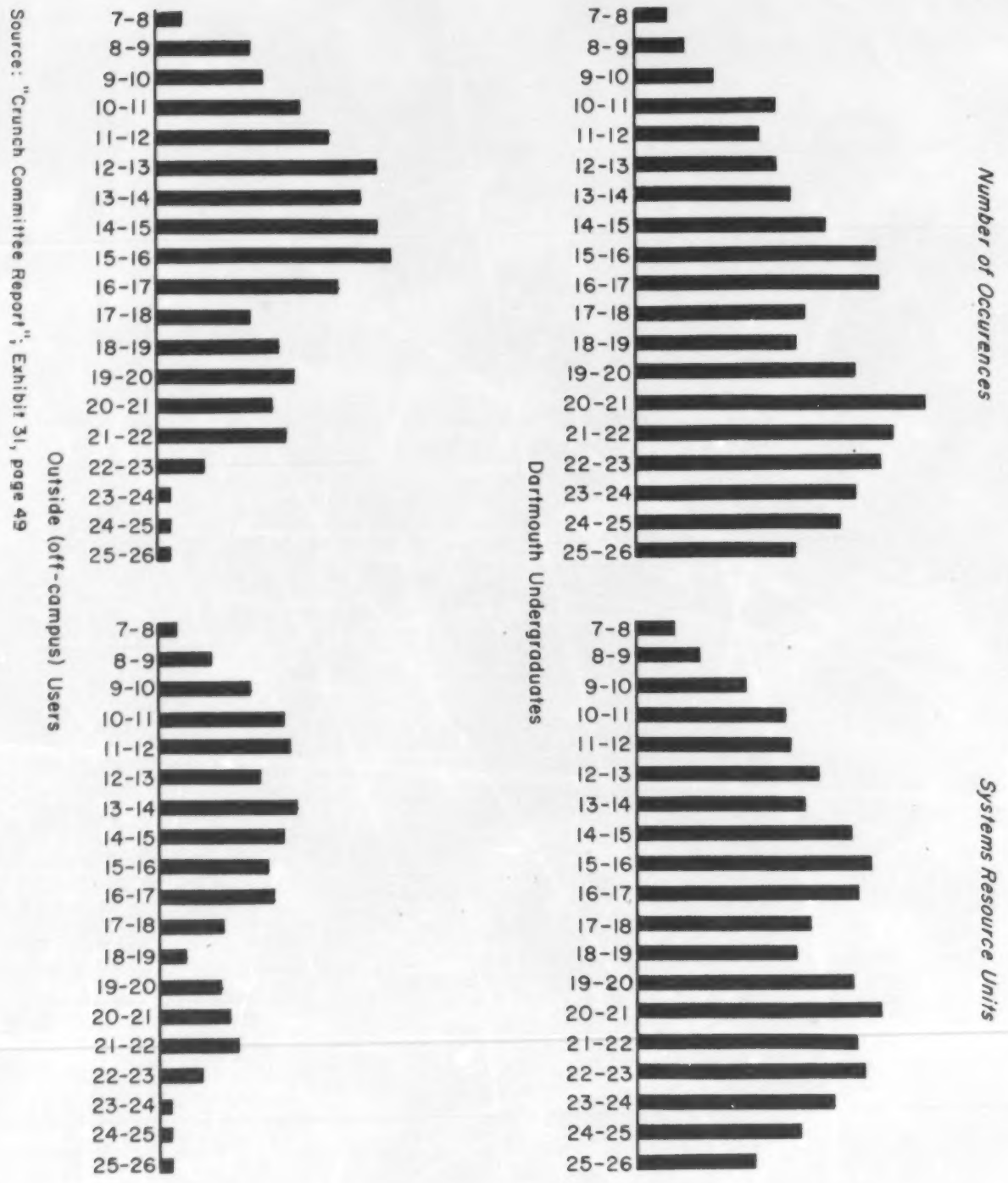
FIGURE 19

USE OF SYSTEM RESOURCE UNITS
BY CATEGORY OF USER, MAY 27, 1976

c 7

FIGURE 20

COMPARISON OF SYSTEM RESOURCE UNITS CONSUMED
BY DARTMOUTH UNDERGRADUATES AND OUTSIDE USERS



Source: "Crunch Committee Report"; Exhibit 31, page 49

FIGURE 21

COMPARISON OF SYSTEM RESOURCE UNITS CONSUMED
BY ADMINISTRATIVE AND KIEWIT USERS

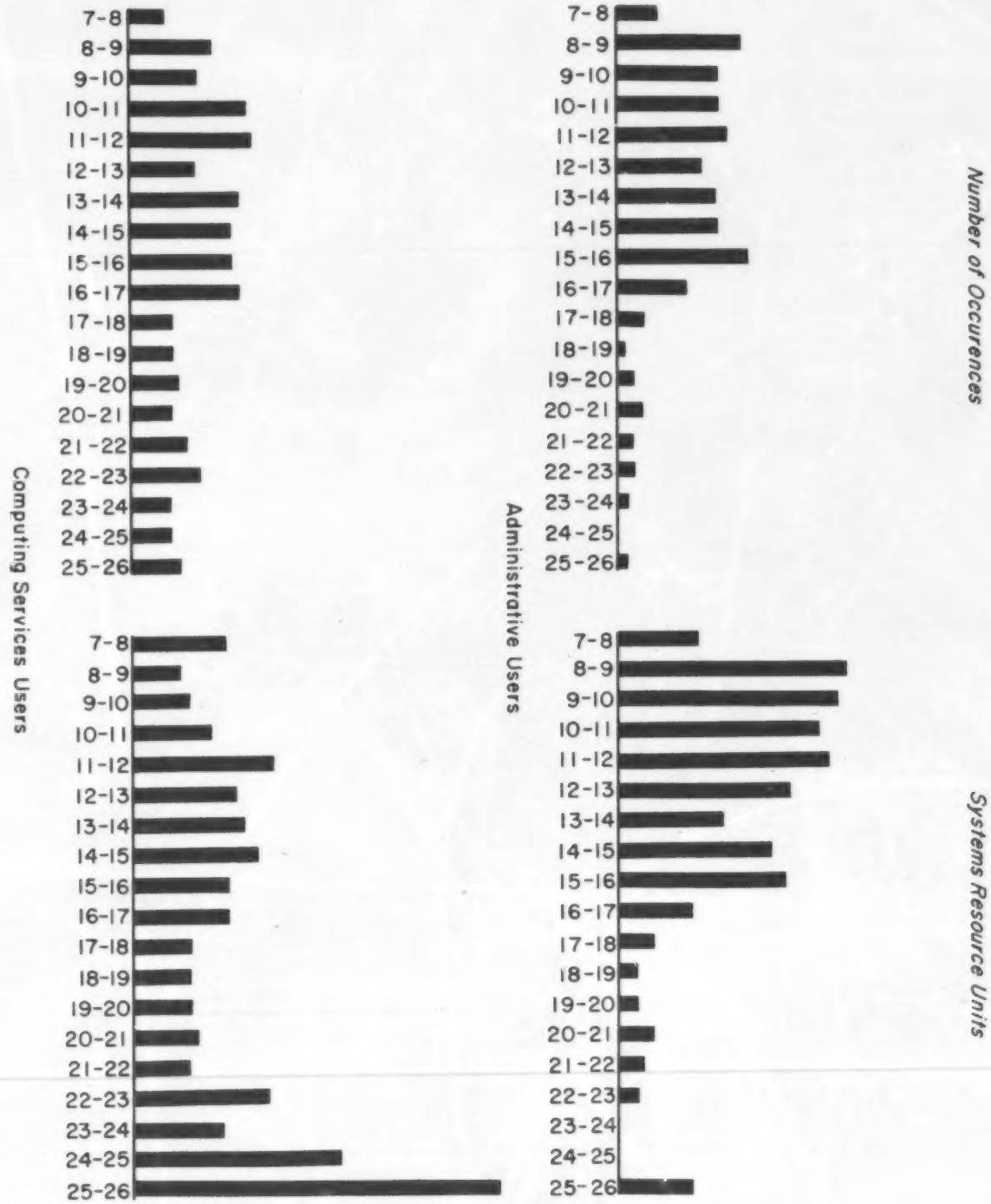


TABLE 16

SUMMARY OF DTSS SYSTEM PERFORMANCE DURING ANNUAL PEAK USAGE
MAY, 1973-1976

	G-635			66/40
	MAY 1973	MAY 1974	MAY 1975	MAY 1976
Scheduled hours of operation	449	379	459	447
Number of days of operation	26	22	27	26
Interruptions to service during official time sharing	9	6	4	8
Total jobs	434,536	391,924	520,071	690,228
Average number of jobs per day	19,389	17,815	21,670	28,759
Average number of jobs per minute	16	16	17	33
Job size				
Less than 1K	3	8	3	0
1K to 4K	12	15	18	12
4K to 8K	30	38	42	49
8K to 16K	48	37	34	37
More than 16K	7	2	3	2
Percentage of jobs which terminate within specified number of swaps[a]				
No swapping required	40	35	46	50
1 swap required	29	25	23	17
3 swaps required	12	12	11	12
7 swaps required	8	9	8	10
More than 7 swaps required	11	12	9	11
CPU seconds of run time per job				
.25 second	57	58	56	56
.5 second	13	13	12	12
1 second	10	9	10	10
2 seconds	7	7	7	7
4 seconds	5	5	6	6
8 seconds	3	3	4	4
16 seconds	2	2	2	2
More than 16 seconds	3	3	3	3
CPU utilization				
Percentage of central processor resources used	39	44	40	66
Percentage of time idle	36	15	28	4
Percentage of resources used for overhead[b]	25	41	32	30
Number of simultaneous users				
Average number of simultaneous users	68	88	73	97
Maximum number of simultaneous users	127	162	148	174
Length of user session				
0 to 15 minutes	53	54	53	56
16 to 30 minutes	16	17	16	16
31 to 45 minutes	9	10	9	10
More than 45 minutes	18	19	18	19
CPU used per user session				
0 to 1 second	53	47	48	52
1 to 4 seconds	19	18	17	15
4 to 10 seconds	11	11	11	11
10 to 32 seconds	9	10	11	12
More than 32 seconds	8	7	10	10

[a]Swapping is the process of transferring programs back and forth between high-speed main (MOS) memory and mass storage (disk memory).

[b]Overhead includes communication processor overhead, system overhead, and CPU resources which are inaccessible because of hardware bottlenecks.

TABLE 17

66/40 RESPONSE TIMES, MAY 1976

TASKS	"GOOD" RESPONSE	NUMBER OF SECONDS REQUIRED FOR COMPLETION 7-8 a.m.	9-10 a.m.	1-2 p.m.	3-4 p.m.
10 Interactions	< 75	58	67	58	68
10 Seconds CPU	< 30	11	33	37	79
100 I/O operations	< 30	5	18	20	40
10 Compilations	< 60	12	44	52	103
Number of Foreground users		8	72	87	115

Table 16 compares system performance during the month of May in 1973, 1974, 1975 and 1976. The significant increase in productivity on the 66/40 computer is obvious. The total number of jobs processed and the average and maximum user load increased by 33%, and the jobs processed per minute nearly doubled. Although the average job was slightly larger in 1976 than in 1975, it was more likely to be run to completion without "swapping out." The characteristics of the user session changed very little, and the profile of jobs by run time remained exactly the same. Most impressive was the fact that in 1976 66% of the available central processor resources were used and only 5% were idle.

In summary 33% more users were being served by DTSS in May 1976 than in May of the preceding year, and larger jobs were generally being processed more quickly.

System Response

The "Crunch Committee's" study of system response measured four representative types of jobs and judged response to be "good" if the tasks were completed within a prescribed time limit. These tasks and criteria are shown in Table 17.

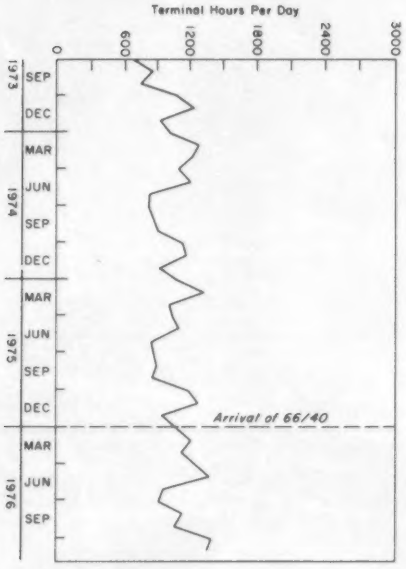
Task	*Limits*
10 interactions accomplished	< 75 seconds
10 seconds of central processor time delivered	< 30 seconds
100 I/O operations performed	< 30 seconds
10 compilations completed	< 60 seconds

The study found that, under conditions of peak loading, there was a close correlation between the time required for 100 I/O operations, the time required for 10 seconds of run time, and the time for 10 compilations; however, there was no correlation between these three measures and the length of time necessary to accomplish 10 interactions.

Despite the fact that the G-635 was replaced by the more powerful 66/40 in February 1976, the figures in Table 17 show that response times for all tasks except ten interactions exceeded the "good" response criteria during the peak period (3-4 p.m.) of use. The worst deviations from "good response" occurred in the measurements of CPU seconds and compilations. The availability of I/O services was slightly out of bounds, but did not appear to be a major problem. The control mechanisms which are to be introduced will be designed to change this pattern of use by providing unacceptable response time to those who demand excessive system resources during such peak periods.

FIGURE 22

TERMINAL CONNECT HOURS PER DAY
1973-1976



Long-term Growth

The following graphs show growth in the use of terminal connect services, input-output services (I/O) and on-line storage during the three-year period covered by this report. (Comparable growth in the use of the central processor is shown in Figure 10, section 6.

Terminal Connect Services: The new computer seems to have had little impact on the number of terminal hours used per day of DTSS operation, but as seen in Figures 23 and 10, *productivity* per hour increased significantly.

I/O Services: The increased I/O capacity of the 66/40 computer is reflected in the abrupt upturn in the graph immediately following the acquisition of the 66/40.

Storage: The graph shows a planned dip in saved storage, just prior to the acquisition of the 66/40 and then an increased rate of growth following the installation of the new system with its greatly increased storage capacity.

FIGURE 23

DAILY INPUT/OUTPUT USE
1973-1976

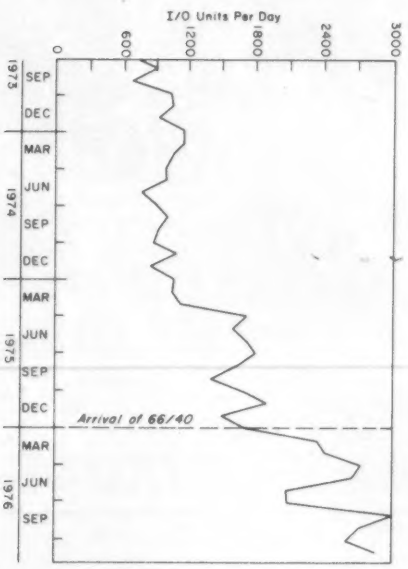


FIGURE 24

NUMBER OF WORDS STORED
1973-1976